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(54) **FLASH ELECTRONIC DISK WITH RAID CONTROLLER**

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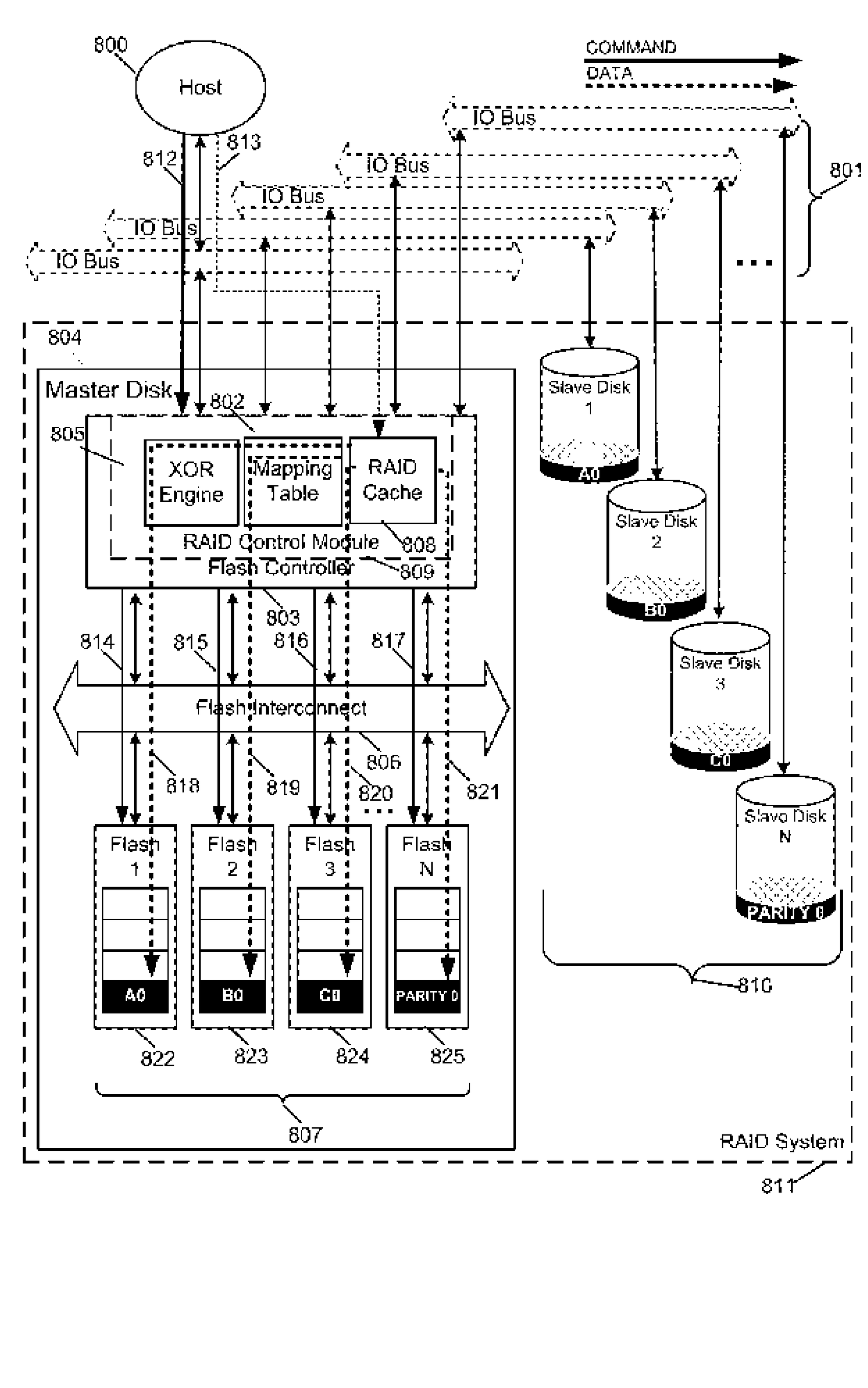
(57) **ABSTRACT**

In an embodiment of the invention, a method is presented to operationally integrate one or more RAID control mechanisms into a flash electronic disk controller. The method includes incorporating one or more RAID features into a flash electronic disk by adding one or more RAID components in a flash controller, wherein the flash electronic disk includes a RAID control module to control the one or more RAID components; receiving a read or write operation command at a flash controller from a host; translating the read or write operation command into a command format understood by one or more flash controllers; translating the command format into an instruction format understood by one or more flash memory devices; and accessing one or more memory locations in the one or more flash memory devices according to the instruction format to perform a read or write operation for the host.

26 Claims, 17 Drawing Sheets



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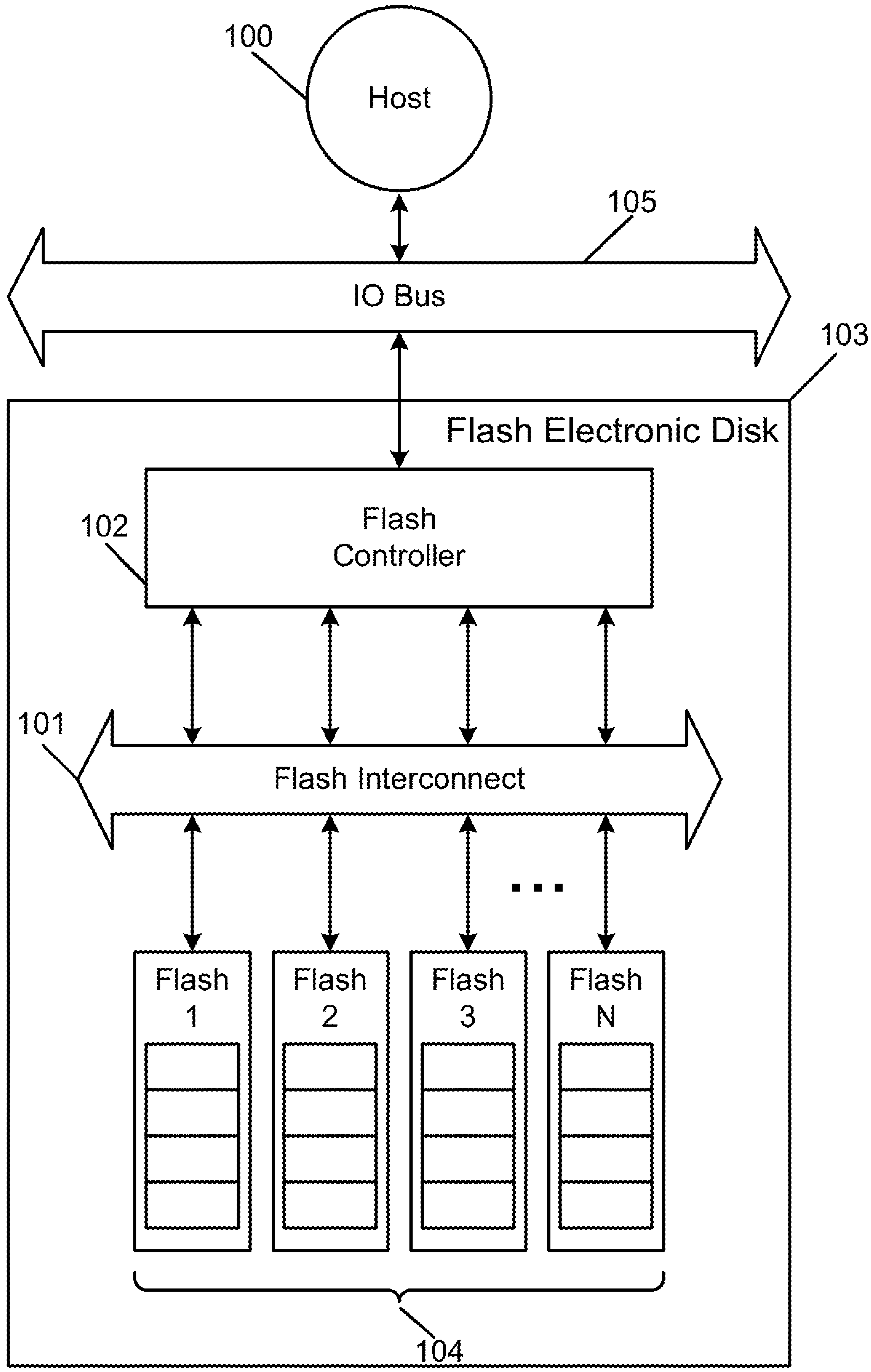
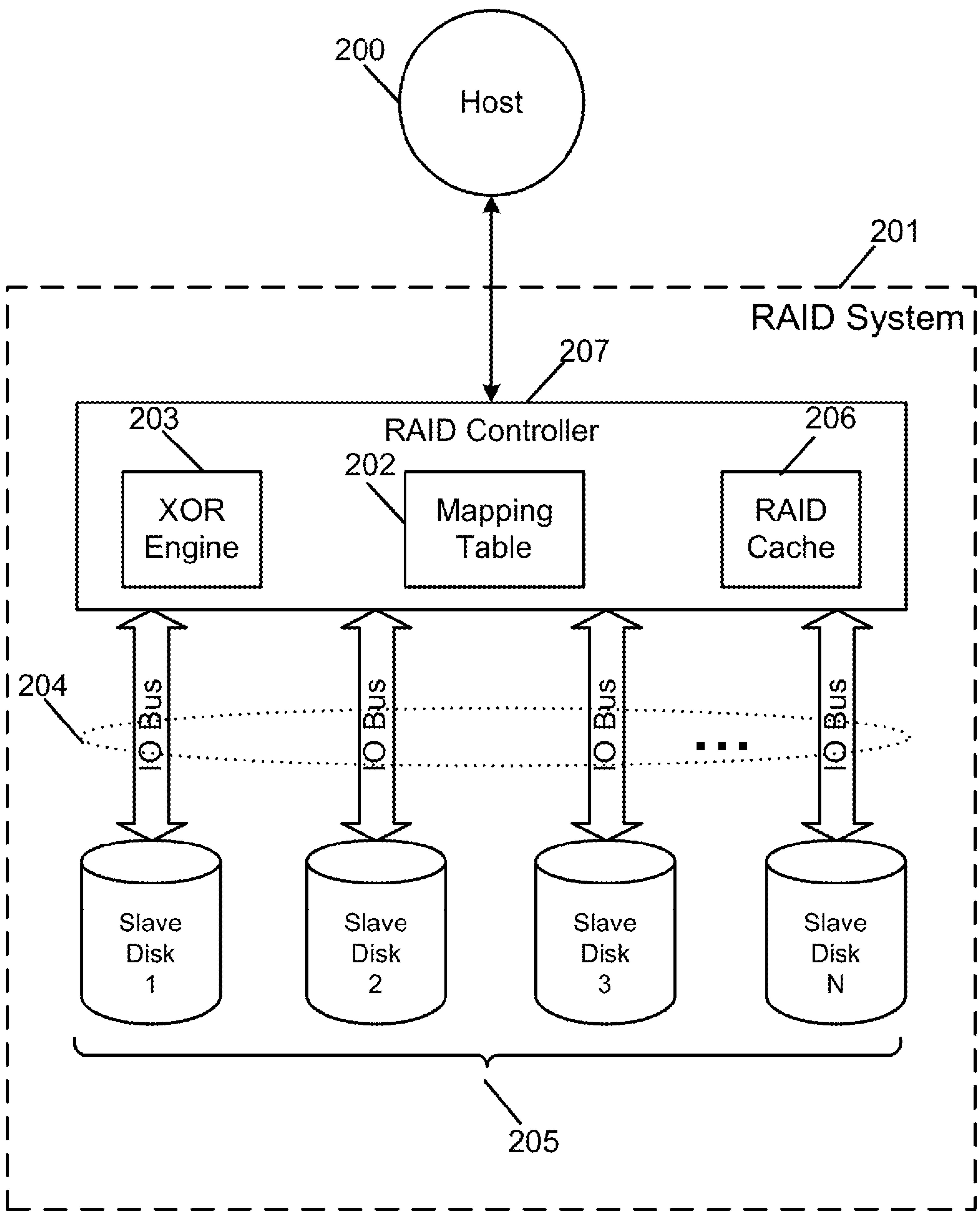
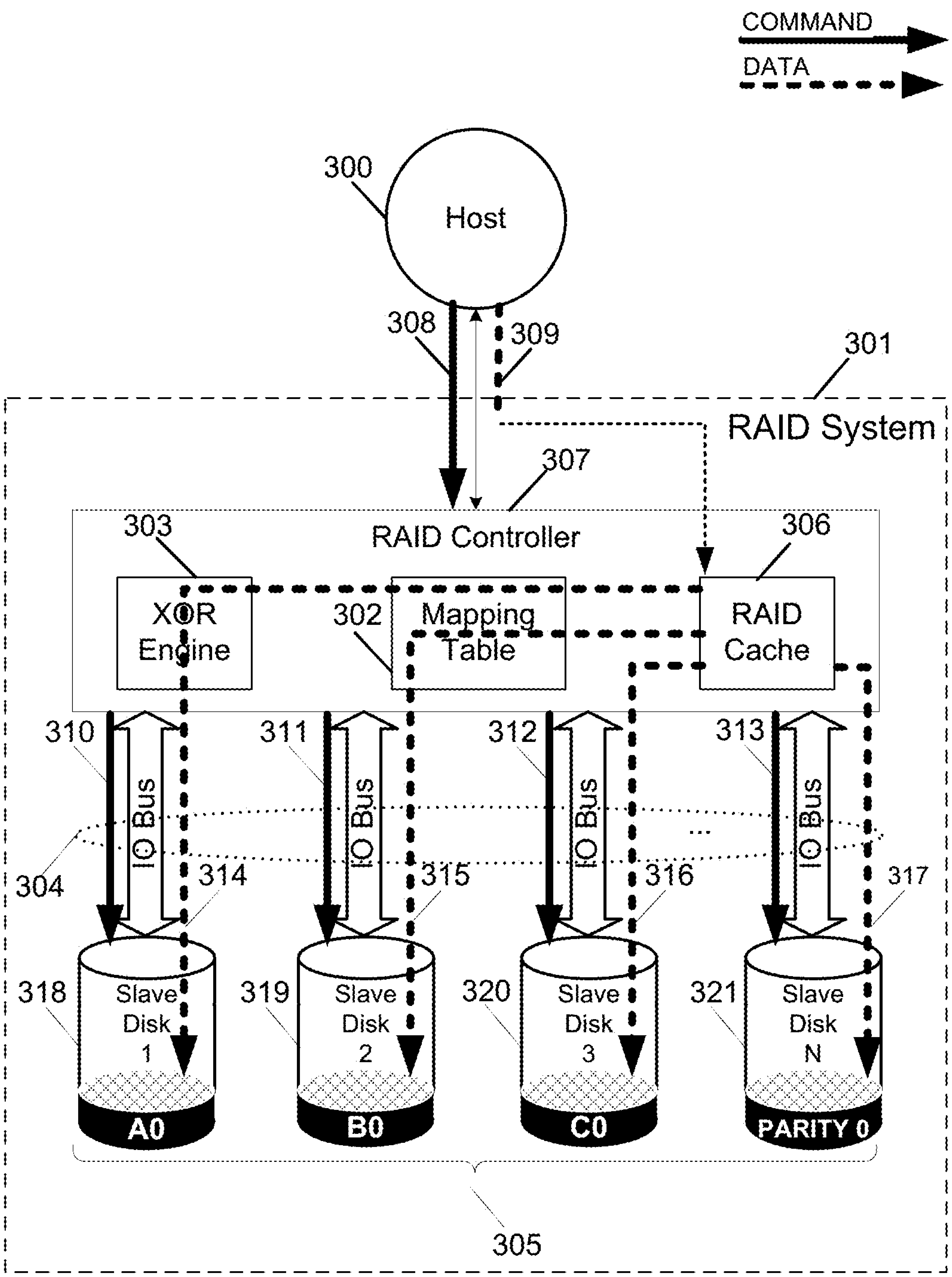


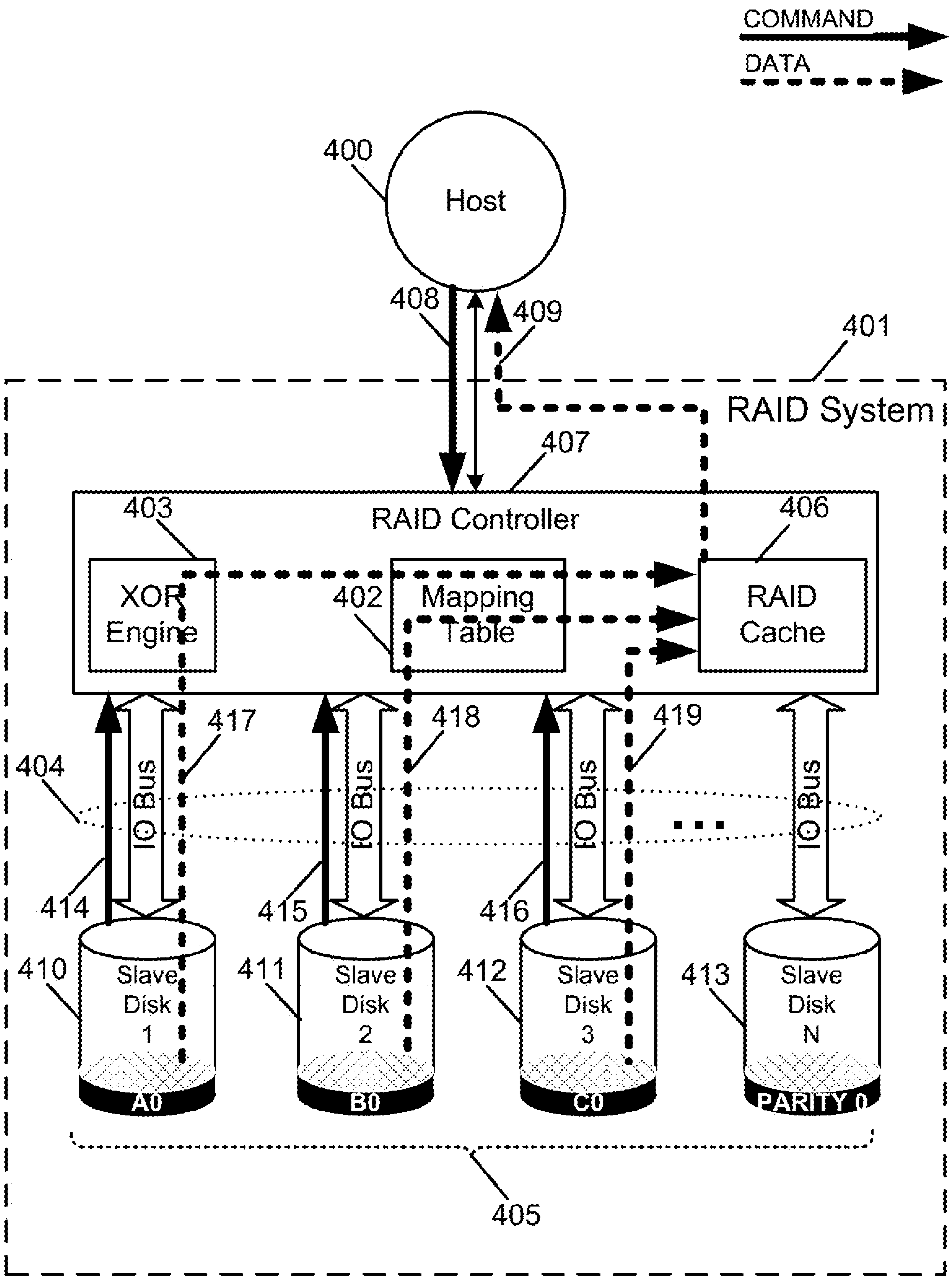
PRIOR ART
FIG. 1



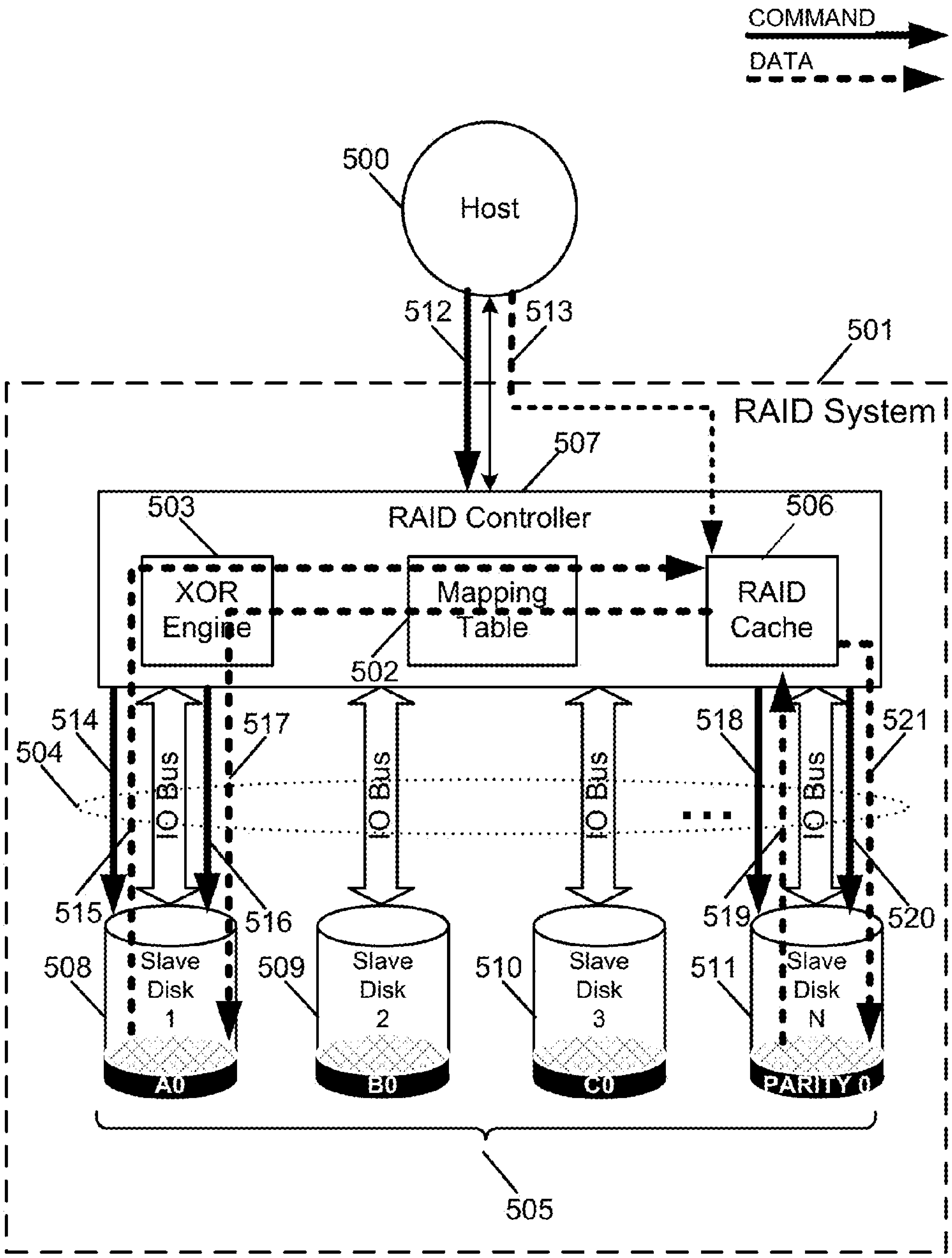
PRIOR ART
FIG. 2



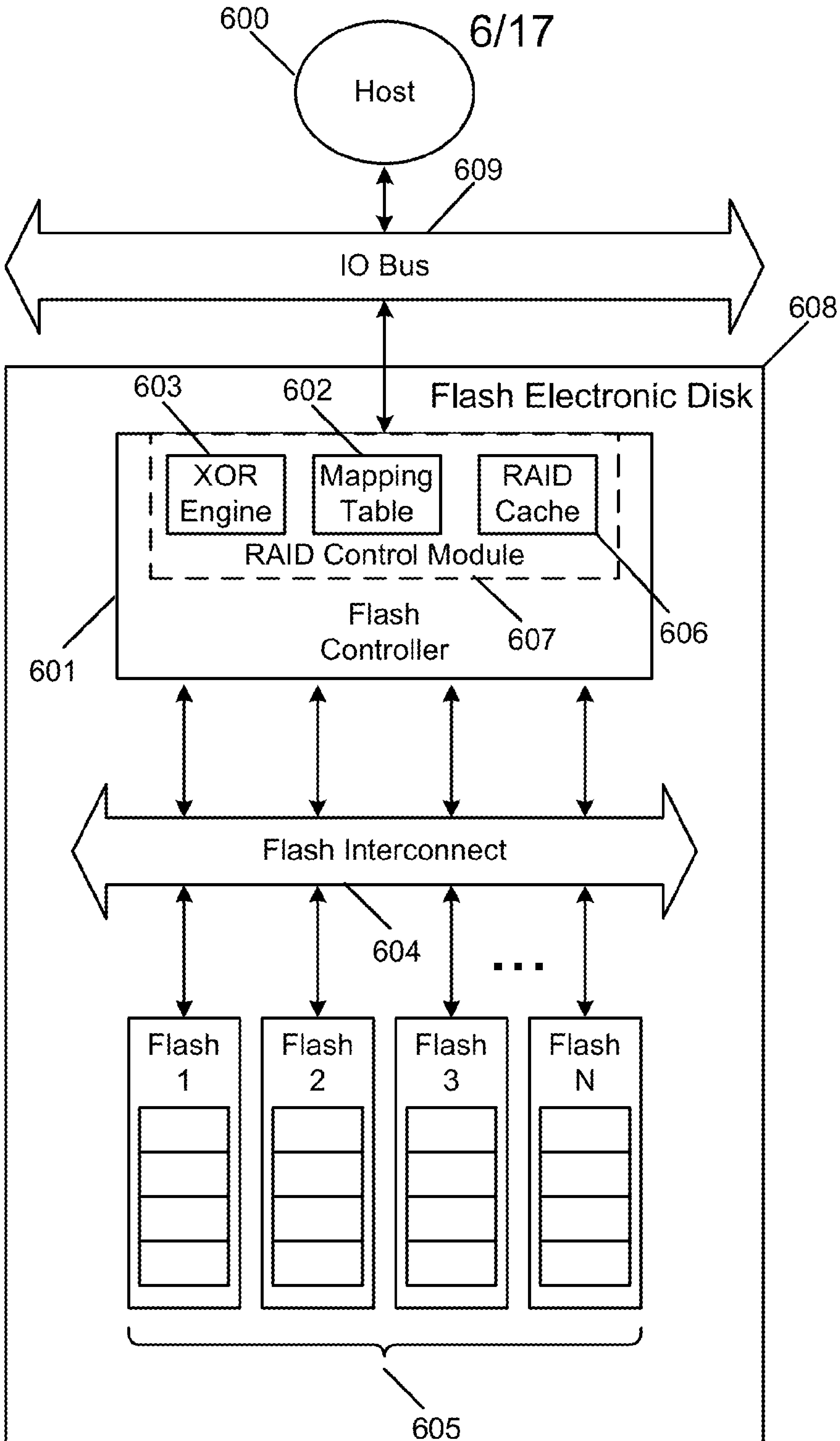
PRIOR ART
FIG. 3



PRIOR ART
FIG. 4

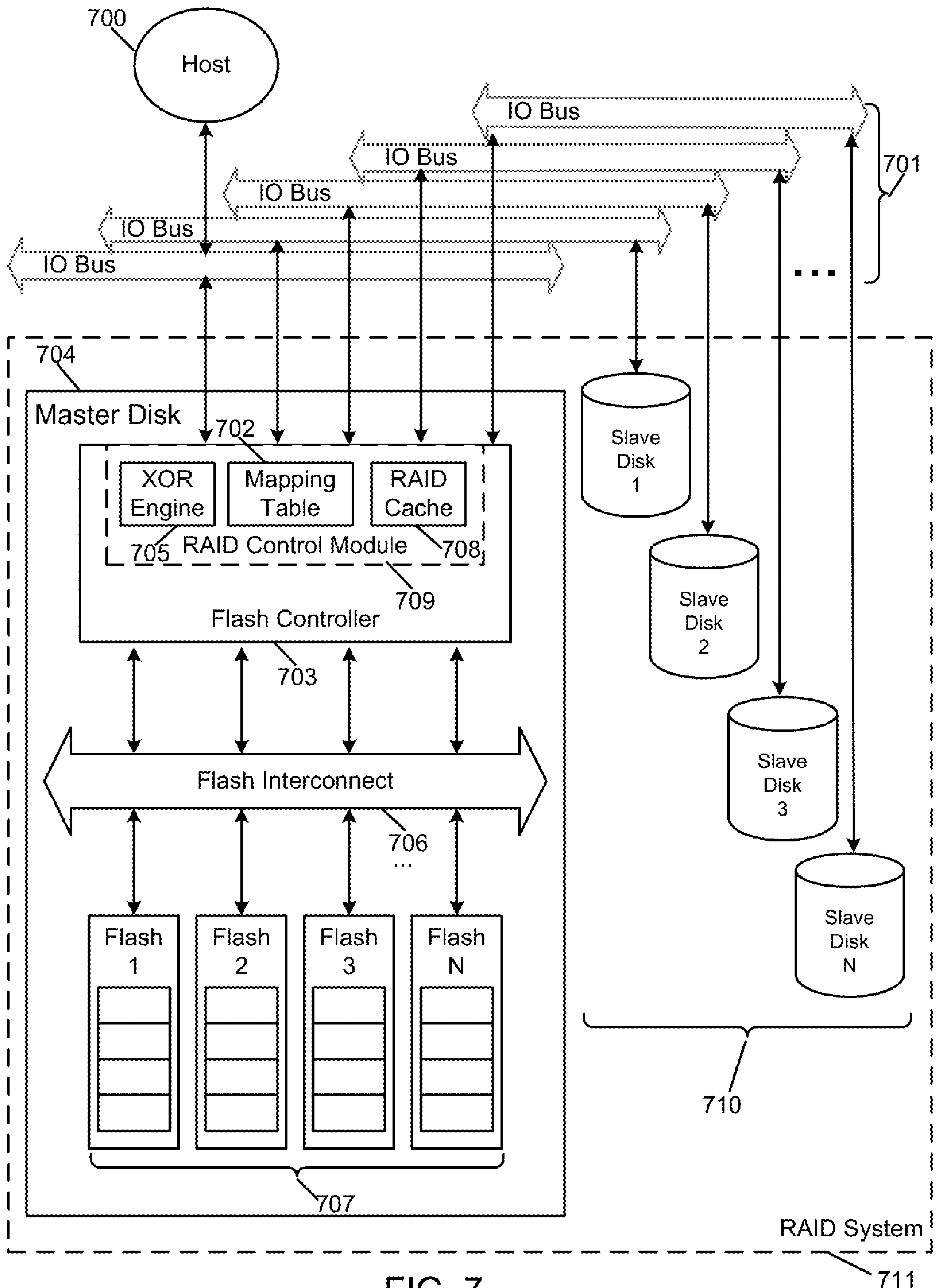


PRIOR ART
FIG. 5



6/17
600
Host
609
IO Bus
608
Flash Electronic Disk
603
602
XOR Engine
Mapping Table
RAID Cache
RAID Control Module
Flash Controller
601
607
606
Flash Interconnect
604
...
Flash 1
Flash 2
Flash 3
Flash N
605

FIG. 6



700
Host
IO Bus
IO Bus
IO Bus
IO Bus
IO Bus
701
...
704
Master Disk
702
XOR Engine
Mapping Table
RAID Cache
705
RAID Control Module
708
709
Flash Controller
703
Flash Interconnect
706
...
Flash 1
Flash 2
Flash 3
Flash N
707
Slave Disk 1
Slave Disk 2
Slave Disk 3
Slave Disk N
710
RAID System
711

FIG. 7

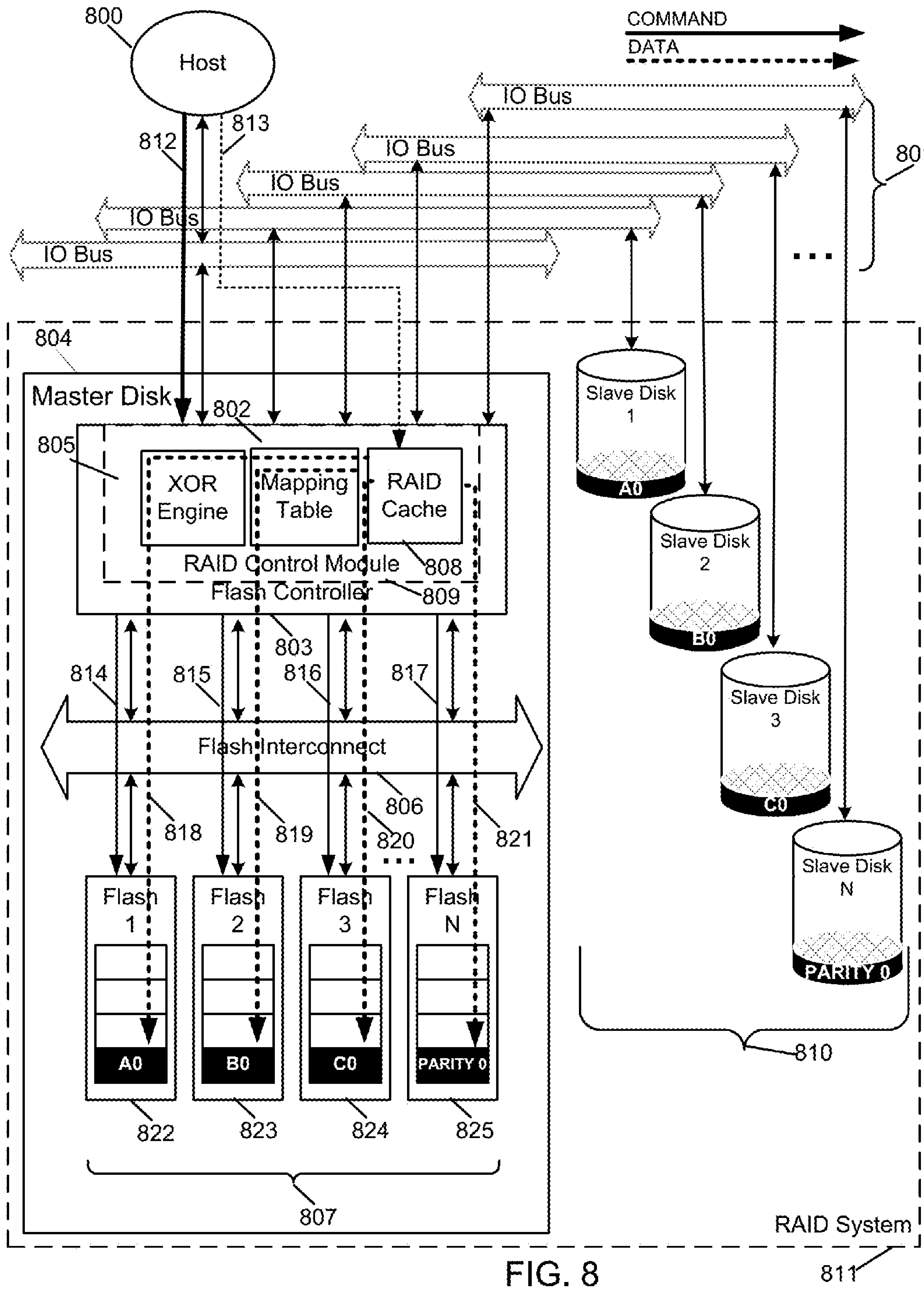

800
Host
COMMAND
DATA
IO Bus
IO Bus
IO Bus
IO Bus
IO Bus
801
812
813
804
Master Disk
802
805
XOR Engine
Mapping Table
RAID Cache
RAID Control Module
Flash Controller
808
809
803
814
815
816
817
Flash Interconnect
806
818
819
820
821
Flash 1
Flash 2
Flash 3
Flash N
A0
B0
C0
PARITY 0
822
823
824
825
807
Slave Disk 1
Slave Disk 2
Slave Disk 3
Slave Disk N
810
RAID System
811

FIG. 8

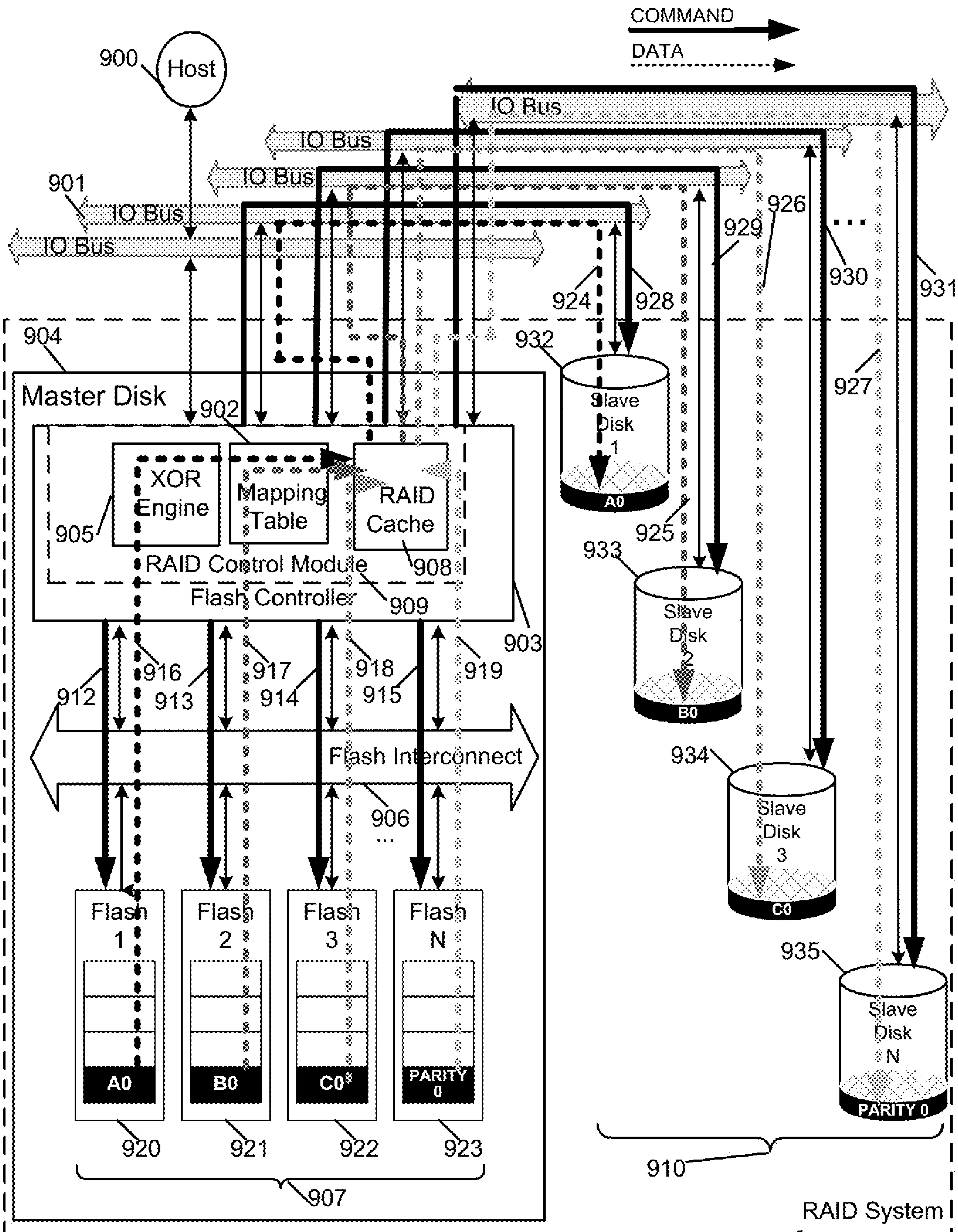

COMMAND
DATA
900
Host
901
IO Bus
IO Bus
IO Bus
IO Bus
IO Bus
926
929
924
928
930
931
904
932
927
Master Disk
902
Slave Disk 1
A0
XOR Engine
Mapping Table
RAID Cache
905
925
933
RAID Control Module
908
Flash Controller
909
Slave Disk 2
B0
903
916
917
918
919
912
913
914
915
Flash Interconnect
934
906
Slave Disk 3
C0
Flash 1
Flash 2
Flash 3
Flash N
935
A0
B0
C0
PARITY 0
Slave Disk N
PARITY 0
920
921
922
923
910
907
RAID System
911

FIG. 9

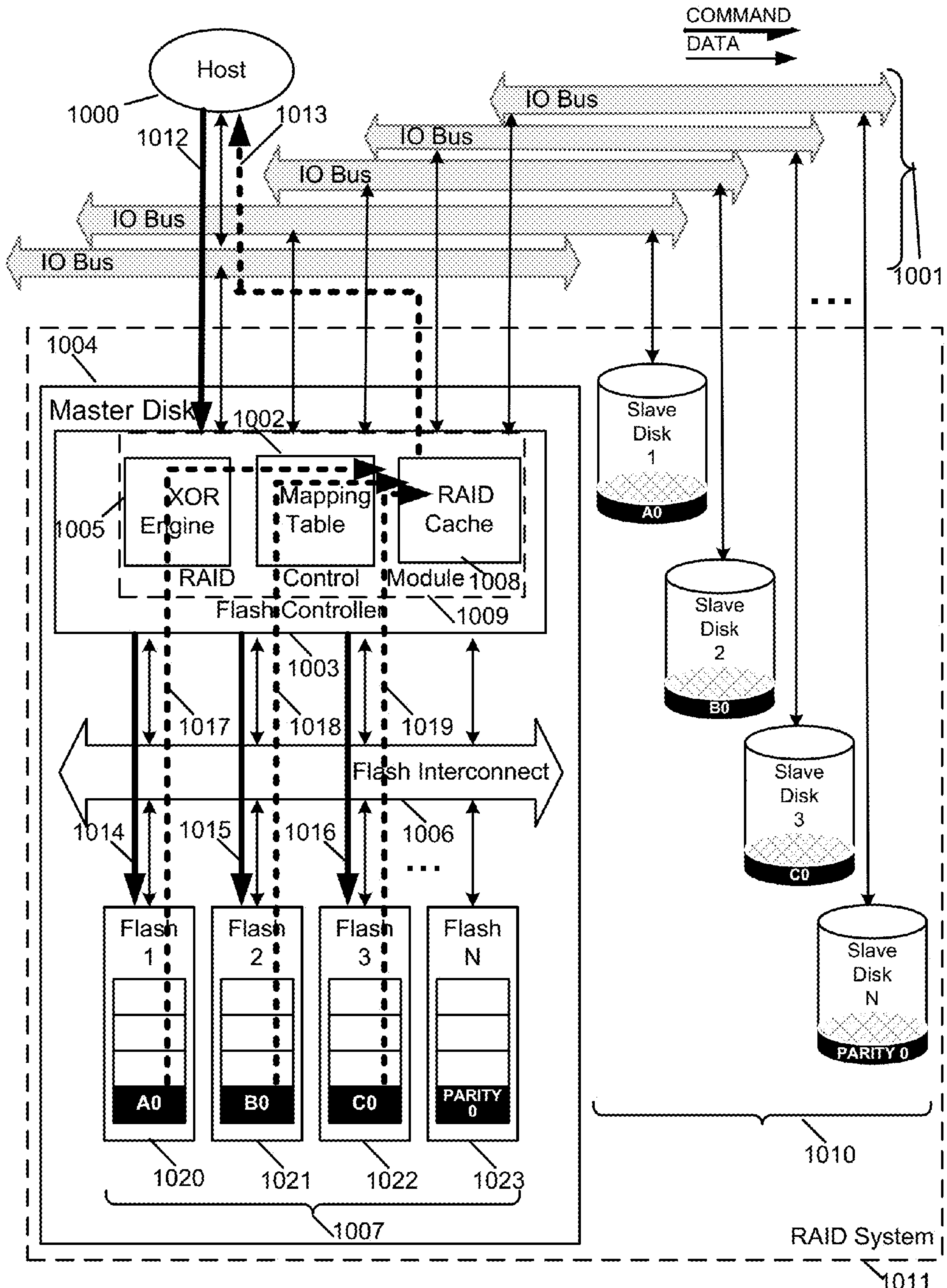

COMMAND
DATA
Host
1000
1012
1013
IO Bus
IO Bus
IO Bus
IO Bus
IO Bus
1001
1004
Master Disk
1002
XOR Engine
Mapping Table
RAID Cache
1005
RAID Control Module
1008
Flash Controller
1009
1003
1017
1018
1019
Flash Interconnect
1014
1015
1016
1006
Flash 1
Flash 2
Flash 3
Flash N
A0
B0
C0
PARITY 0
1020
1021
1022
1023
1007
Slave Disk 1
A0
Slave Disk 2
B0
Slave Disk 3
C0
Slave Disk N
PARITY 0
1010
RAID System
1011

FIG. 10

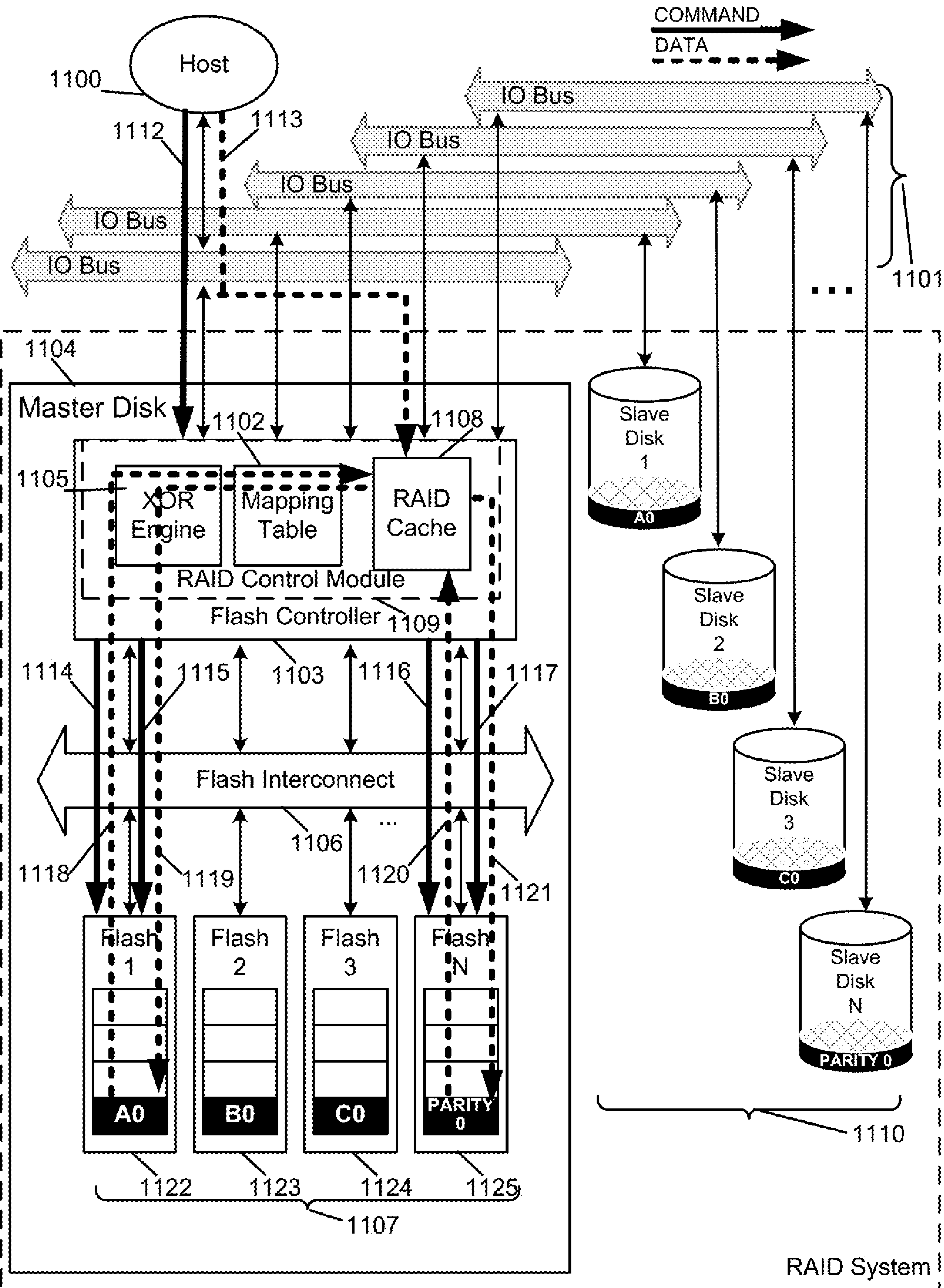
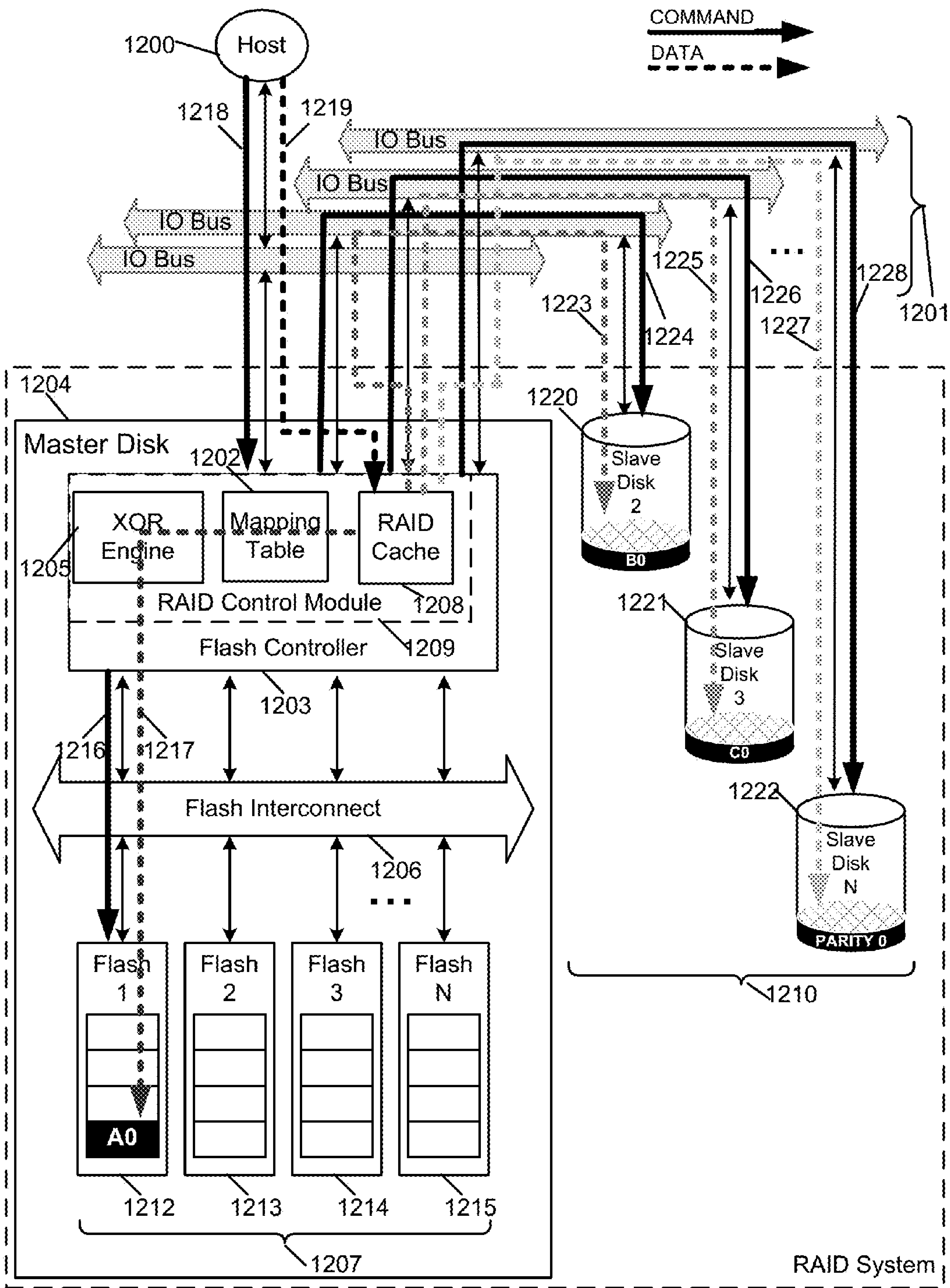

COMMAND
DATA
Host
1100
1112
1113
IO Bus
IO Bus
IO Bus
IO Bus
IO Bus
1101
1104
Master Disk
1102
1108
1105
XOR Engine
Mapping Table
RAID Cache
RAID Control Module
Flash Controller
1109
1114
1115
1103
1116
1117
Flash Interconnect
1106
1118
1119
1120
1121
Flash 1
Flash 2
Flash 3
Flash N
A0
B0
C0
PARITY 0
1122
1123
1124
1125
1107
Slave Disk 1
Slave Disk 2
Slave Disk 3
Slave Disk N
1110
RAID System
1111

FIG. 11



COMMAND
DATA
Host
1200
1218
1219
IO Bus
IO Bus
IO Bus
IO Bus
1201
1225
1226
1228
1223
1224
1227
1204
Master Disk
1202
XOR Engine
Mapping Table
RAID Cache
1205
RAID Control Module
1208
Flash Controller
1209
1203
1216
1217
Flash Interconnect
1206
Flash 1
Flash 2
Flash 3
Flash N
A0
1212
1213
1214
1215
1207
1220
Slave Disk 2
B0
1221
Slave Disk 3
C0
1222
Slave Disk N
PARITY 0
1210
RAID System
1211

FIG. 12

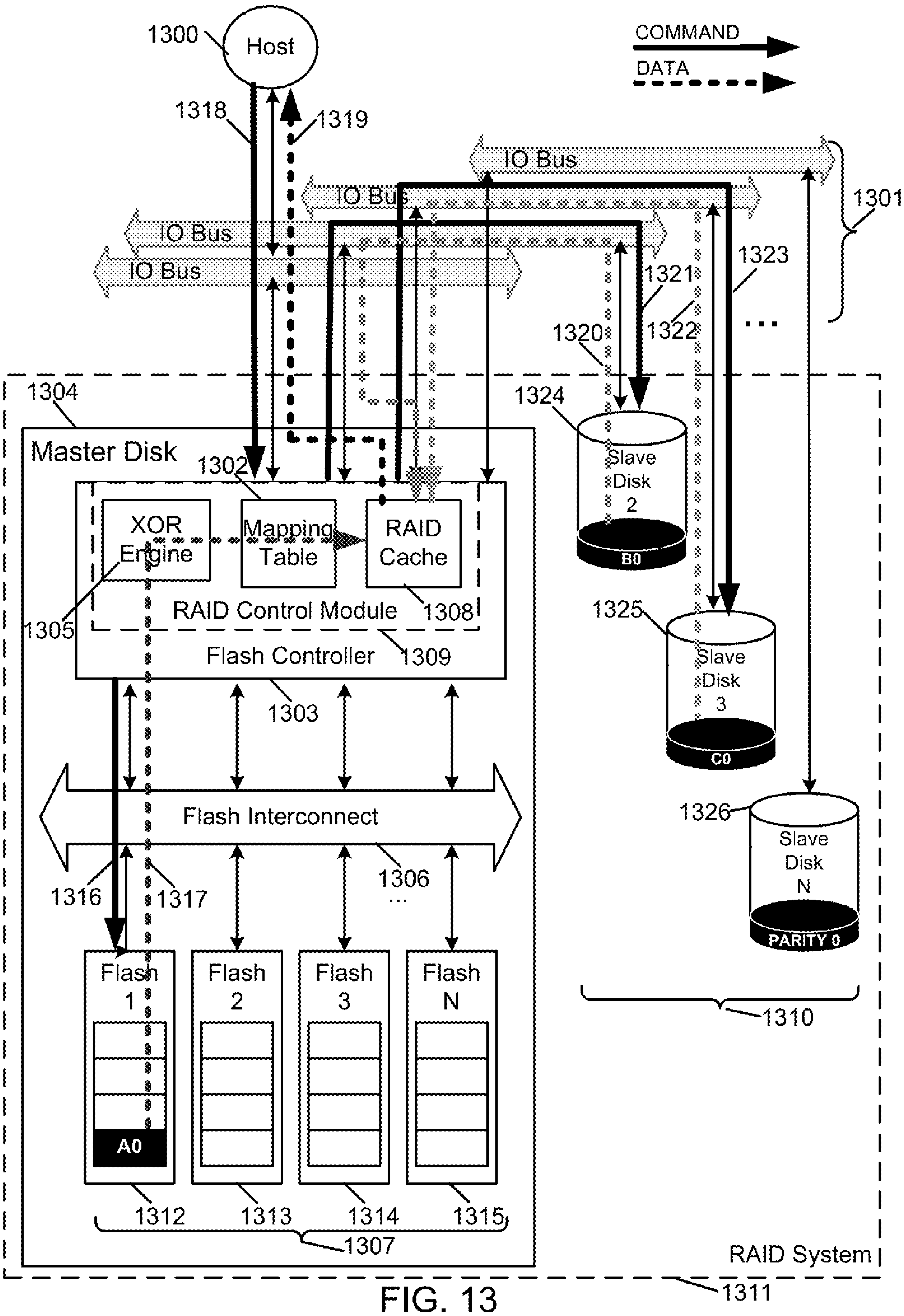

COMMAND
DATA
1300
Host
1318
1319
IO Bus
IO Bus
IO Bus
IO Bus
1301
1321
1323
1320
1322
...
1304
1324
Master Disk
1302
Slave Disk 2
B0
XOR Engine
Mapping Table
RAID Cache
RAID Control Module
1308
1305
1325
Flash Controller
1309
Slave Disk 3
C0
1303
1326
Flash Interconnect
Slave Disk N
PARITY 0
1316
1317
1306
Flash 1
Flash 2
Flash 3
Flash N
A0
1310
1312
1313
1314
1315
1307
RAID System
1311

FIG. 13

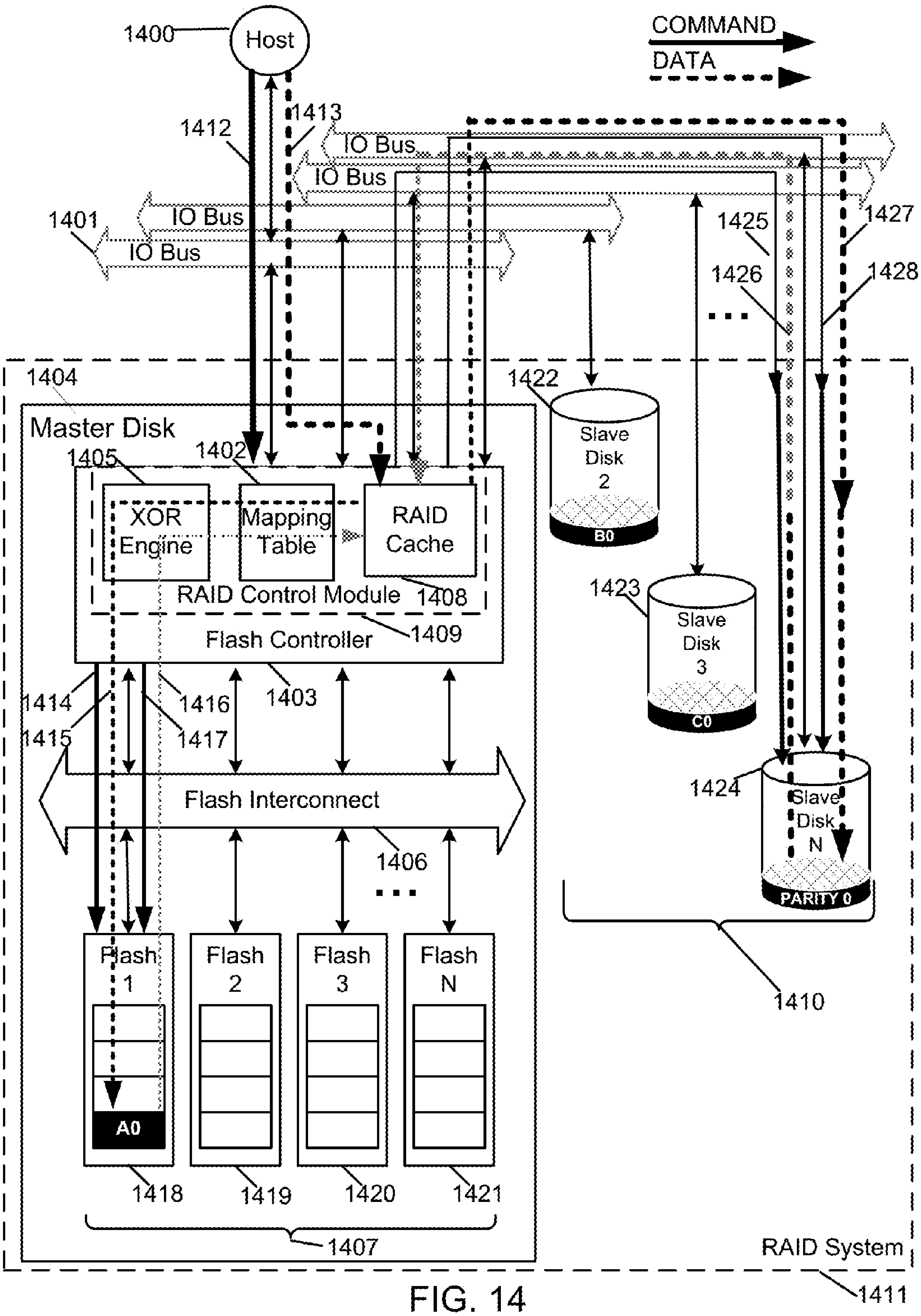

COMMAND
DATA
1400
Host
1412
1413
IO Bus
IO Bus
1401
IO Bus
IO Bus
1425
1427
1426
1428
1404
1422
Master Disk
1405
1402
XOR Engine
Mapping Table
RAID Cache
Slave Disk 2
B0
RAID Control Module
1408
1423
Flash Controller
1409
Slave Disk 3
C0
1414
1416
1403
1415
1417
1424
Flash Interconnect
Slave Disk N
PARITY 0
1406
Flash 1
Flash 2
Flash 3
Flash N
1410
A0
1418
1419
1420
1421
1407
RAID System
1411

FIG. 14

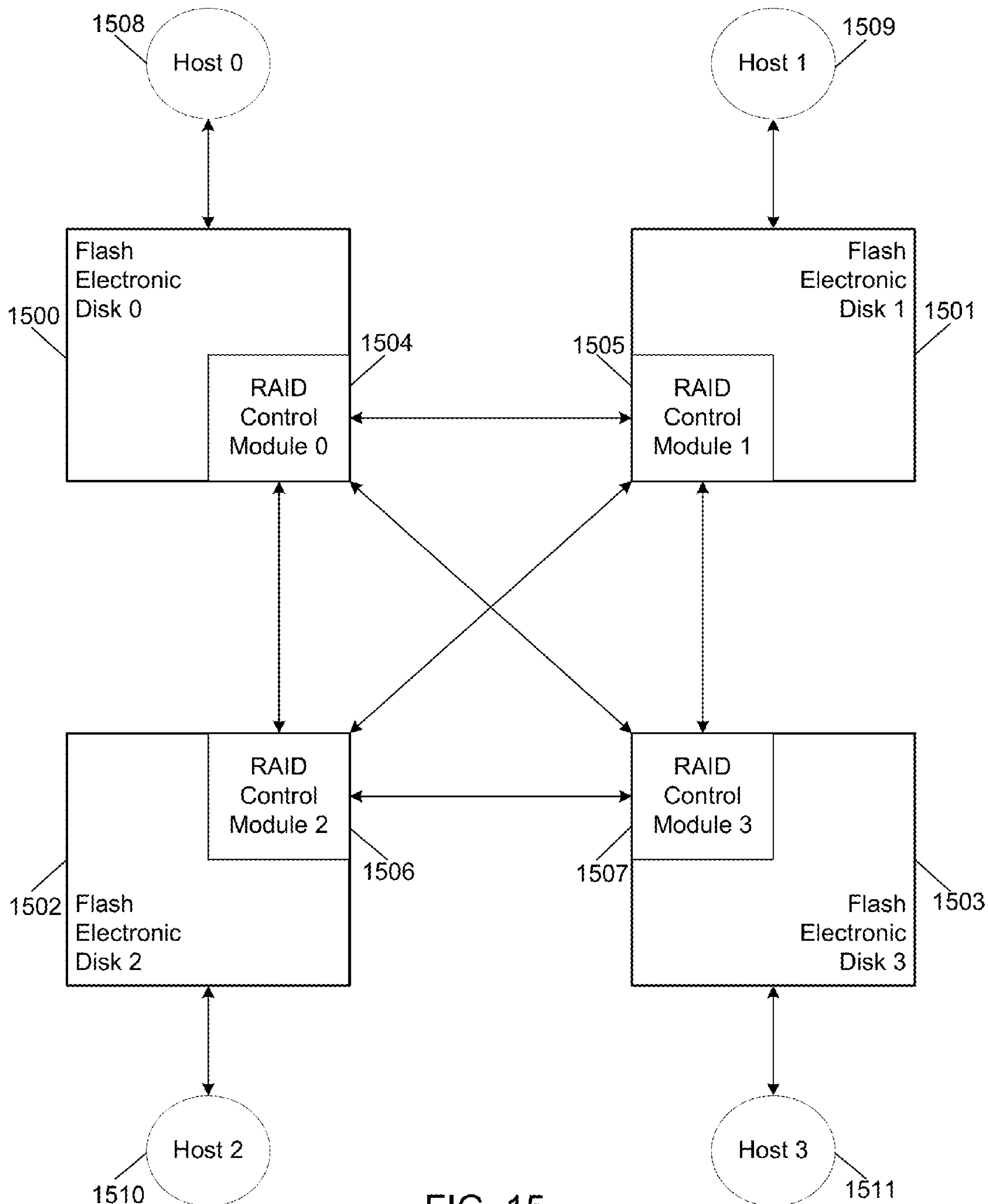

1508
Host 0
1509
Host 1
Flash
Electronic
Disk 0
1500
1504
1505
Flash
Electronic
Disk 1
1501
RAID
Control
Module 0
RAID
Control
Module 1
RAID
Control
Module 2
RAID
Control
Module 3
1506
1507
1502
Flash
Electronic
Disk 2
Flash
Electronic
Disk 3
1503
Host 2
1510
Host 3
1511

FIG. 15

	1602	1604	1606	1608	1610		1612
	Disk Number	**RAID System 0**	**RAID System 1**	**RAID System 2**	**RAID System 3**	**...**	**RAID System N**
1620	Flash Electronic Disk 0	Master	Slave	Slave	Slave	...	Slave
1622	Flash Electronic Disk 1	Slave	Master	Slave	Slave	...	Slave
1624	Flash Electronic Disk 2	Slave	Slave	Master	Slave	...	Slave
1626	Flash Electronic Disk 3	Slave	Slave	Slave	Master	...	Slave
	...	...	...	...	...	...	...
1628	Flash Electronic Disk N	Slave	Slave	Slave	Slave	...	Master

FIG. 16

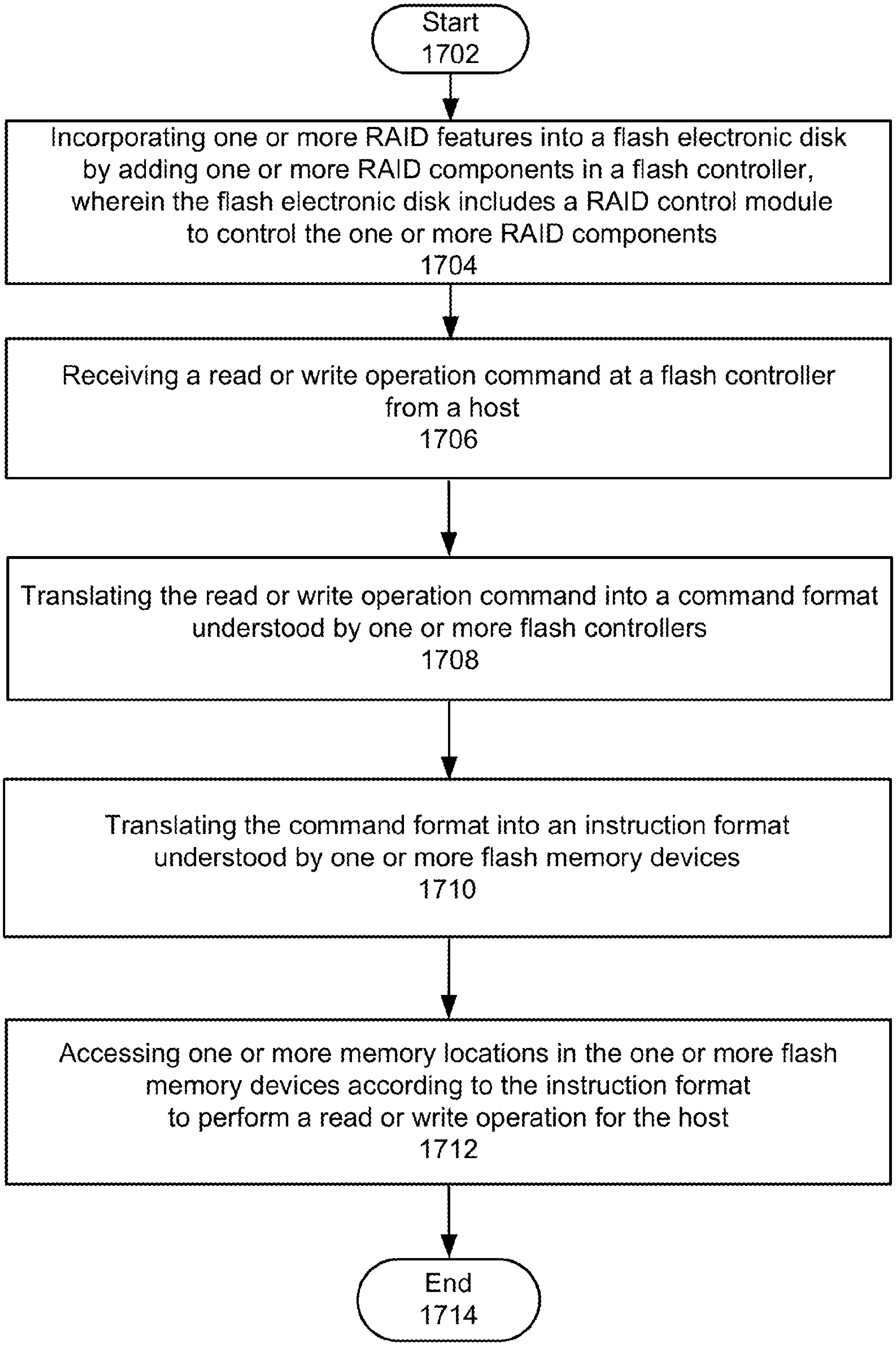

Start
1702
Incorporating one or more RAID features into a flash electronic disk by adding one or more RAID components in a flash controller, wherein the flash electronic disk includes a RAID control module to control the one or more RAID components
1704
Receiving a read or write operation command at a flash controller from a host
1706
Translating the read or write operation command into a command format understood by one or more flash controllers
1708
Translating the command format into an instruction format understood by one or more flash memory devices
1710
Accessing one or more memory locations in the one or more flash memory devices according to the instruction format to perform a read or write operation for the host
1712
End
1714

FIG. 17

FLASH ELECTRONIC DISK WITH RAID CONTROLLER

CROSS-REFERENCE(S) TO RELATED APPLICATIONS

This application claims the benefit of and priority to U.S. Provisional Application 61/801,111, filed 15 Mar. 2013. This U.S. Provisional Application 61/801,111 is hereby fully incorporated herein by reference.

This application relates to U.S. Utility application Ser. No. 14/217,316, "Flash Array RAID in Flash Electronic Disks" which is hereby fully incorporated herein by reference and U.S. Utility application Ser. No. 14/217,291, "Direct Memory Access Controller with RAID Hardware Assist" which is hereby fully incorporated herein by reference.

FIELD

Embodiments of the invention relate generally to computer systems and more particularly to Flash Electronic Disk with RAID Controller.

DESCRIPTION OF RELATED ART

Over the last few years, the storage systems industry has witnessed an increasing trend in shifting data storage from mechanical hard disk drives (HDD) to solid state devices (SSD), the Flash Electronic Disk being one of them. This is brought about by a number of advantages in using SSD's over HDD's, the most notable ones are increased data accessing speed, increased reliability in terms of data integrity and physical stress, and prolonged wear and tear.

The increase in data accessing speed opened up a wide range of applications that were used to be shelved because of the memory-access bottleneck. With the coming of Flash Electronic Disks, data-intensive applications now have a chance to come into reality. The absence of rotating mechanical disks in Flash Electronic Disks allowed more memory intensive applications that are physically demanding, such as military applications, shock prone environments and the like, to come into shape.

Trends in the market today point to an increasing demand for SSDs because of its fast memory access speeds. Memory intensive applications, such as database interfaces, are slowly coming into shape as the memory access bottleneck is loosened up. In the advent of memory intensive applications, it is imperative that systems should have reliable and stable data integrity measures. The most reliable data integrity system to date is the RAID system, which has been applied extensively to many computer systems using HDDs. The RAID system uses a simple architecture where data is striped or mirrored to a number of disks. All possible implementations of redundancy are already considered in its many configurations. These principles can also be applied to flash electronic disks to boost data integrity.

Conventional RAID systems prefer implementing RAID Controllers as a separate hardware entity. This is because RAID controls are computations-extensive, that when implemented in firmware, a big chunk of the CPU resource is eaten up. This invention helps to unload the firmware of a computational burden, as this invention implements RAID in hardware, but it takes it a step further. There will be no separate hardware entity for the RAID controls as it will all be integrated into the disk itself, producing a Flash Electronic Disk that is also a RAID Controller at the same time.

SUMMARY

The Flash Electronic Disks are known for its stable and reliable performance over traditional HDDs due to the absence of mechanical components. An embodiment of this invention aims to fortify the existing data integrity badge of Flash Electronic Disks by integrating RAID measures into the disk. Flash Electronic Disks in a RAID configuration would be by far, the most reliable storage system to date.

An embodiment of this invention presents a method and system for implementing RAID for Flash Electronic Disks. The invention integrates RAID control mechanisms into the Flash Electronic Disk controllers, eliminating the need for a separate RAID controller hardware, with minimal firmware intervention. The system and method uses the principles of RAID in addressing the issues brought about by physical disk crashes. The invention merges the benefits of using Flash Electronic Disks and the capabilities of RAID in data integrity, such as hot pluggable disks, into a Flash Electronic Disk. The system and method supports all RAID levels via configurable RAID controller. The system and method also provides possible RAID configurations for the disks over generic IO Interfaces.

In another embodiment of the invention, a method and system for implementing a Flash Electronic Disk with support for Redundant Array of Inexpensive Disks (RAID) system is presented. The method and system include a RAID Control Module that interprets RAID commands from any Host, an Exclusive-Or (XOR) Engine for RAID commands with parity computations, a RAID Cache for temporary storage during calculations, and possible RAID configurations for the Flash Electronic Disks via generic IO interfaces such as SATA, SCSI or PCI Express (PCIe). The invention presents a Flash Electronic Disk that is capable of executing RAID Master and Slave functions over conventional links without the need for a separate RAID Controller hardware and without extensive use of firmware processing.

A key idea of embodiments of this invention lies on having Flash Electronic Disks that offer data integrity capabilities of RAID in highly flexible configurations, without sacrificing the high memory accessing speed of Flash Electronic Disks.

BRIEF DESCRIPTION OF DRAWINGS

So that the manner in which the above recited features, advantages and objects of the present invention are attained and can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to the embodiments thereof which are illustrated in the appended drawings.

It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the present invention may admit to other equally effective embodiments.

FIG. **1** shows a typical prior art Flash Electronic Disk System.

FIG. **2** shows a typical prior art RAID system and its components.

FIG. **3** illustrates a write operation implementation for a typical prior art RAID-5 system.

FIG. **4** illustrates a read operation implementation for a typical prior art RAID-5 system.

FIG. **5** illustrates a read-modify-write operation implementation for a typical prior art RAID-5 system.

FIG. **6** illustrates the modified Flash Electronic Disk Architecture according to an embodiment of the present invention.

FIG. **7** shows a RAID system consisting of ordinary disks and the Flash Electronic Disk according to an embodiment of the present invention.

FIG. **8** is the write operation implementation in a Flash Electronic Disk taking a master role in a RAID-5 system according to an embodiment of the present invention.

FIG. **9** illustrates how the Flash Electronic Disk performs the flushing process according to an embodiment of the present invention.

FIG. **10** is the read operation implementation in a Flash Electronic Disk taking a master role in a RAID-5 system according to an embodiment of the present invention.

FIG. **11** is the read-modify-write operation implementation in a Flash Electronic Disk taking a master role in a RAID-5 system according to an embodiment of the present invention.

FIG. **12** is the write operation implementation in a Flash Electronic Disk taking dual roles in a RAID-5 system according to an embodiment of the present invention.

FIG. **13** is the read operation implementation in a Flash Electronic Disk taking dual roles in a RAID-5 system according to an embodiment of the present invention.

FIG. **14** is the read-modify-write operation implementation in a Flash Electronic Disk taking dual roles in a RAID-5 system according to an embodiment of the present invention.

FIG. **15** is a possible configuration of four Flash Electronic Disks in a RAID System according to an embodiment of the present invention.

FIG. **16** summarizes the multi-RAID configuration of multiple Flash Electronic Disks according to an embodiment of the present invention.

FIG. **17** illustrates a method to operationally integrate one or more RAID control mechanisms into a flash electronic disk controller, in accordance with one embodiment of the invention.

DETAILED DESCRIPTION

In the following detailed description, for purposes of explanation, numerous specific details are set forth to provide a thorough understanding of the various embodiments of the present invention. Those of ordinary skill in the art will realize that these various embodiments of the present invention are illustrative only and are not intended to be limiting in any way. Other embodiments of the present invention will readily suggest themselves to such skilled persons having the benefit of this disclosure.

In addition, for clarity purposes, not all of the routine features of the embodiments described herein are shown or described. One of ordinary skill in the art would readily appreciate that in the development of any such actual implementation, numerous implementation-specific decisions may be required to achieve specific design objectives. These design objectives will vary from one implementation to another and from one developer to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming but would nevertheless be a routine engineering undertaking for those of ordinary skill in the art having the benefit of this disclosure. The various embodiments disclosed herein are not intended to limit the scope and spirit of the herein disclosure.

Preferred embodiments for carrying out the principles of the present invention are described herein with reference to the drawings. However, the present invention is not limited to the specifically described and illustrated embodiments. A person skilled in the art will appreciate that many other embodiments are possible without deviating from the basic concept of the invention. Therefore, the principles of the present invention extend to any work that falls within the scope of the appended claims.

As used herein, the terms "a" and "an" herein do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced items.

FIG. **1** shows a typical prior art Flash Electronic Disk architecture. A Flash Electronic Disk **103** is composed mainly of Flash Memory Devices **104**, linked to the Flash Controller **102** by a Flash Interconnect **101**. The Flash Interconnect **101** handles the necessary data passing sequences between the Host **100** and the Flash Memory Devices. The Host **100** is typically a CPU of a computer system which sends out instructions to the disk via the IO Bus **105**. The Flash Electronic Disk **103** mimics an ordinary HDD so that the Host **100** sees it as an ordinary storage device. The Host issues read and write commands to the Flash Electronic Disk as if it is just accessing an ordinary HDD. The Flash Controller **102** of the Flash Electronic Disk translates the instructions from the Host **100** into flash native commands which are understood by the plurality of Flash Memory Devices **104**. FIG. **1** describes a typical storage device system, though in this case, the storage device uses flash memory devices instead of the conventional rotating mechanical disks.

FIG. **2** illustrates a typical prior art RAID system and its components. A RAID system has a RAID Controller **207** that manages a plurality of Slave Disks **205** and makes them appear as just one storage device to the Host **200**. Host **200** is usually a computer CPU that sends out memory transfer instructions to the RAID system **201**. In general, the RAID Controller handles all system-related activities such as communicating to the host, accessing the slave disks, maintaining system information, executing requested transfers and recovering from disk failures. A typical RAID system distributes its data across all the slave disks in a manner commonly referred to as data striping. By allowing more than one slave disk in the system, RAID allows for concurrent access by independent processes. RAID has 5 distinct levels/configurations for redundancy; some users though combine these configurations to produce hybrids that suit their purpose. Most RAID levels employ parity for redundancy, thus requiring the use of combinational logic to implement the equivalent of an Exclusive-OR (XOR) Engine **203**, which is a processing element that performs parity calculations. The RAID Cache **206** is the temporary storage of data commonly used for RAID parity operations. The Mapping Table **202** is used by the RAID Controller **207** to determine which slave disk(s) are being referred to by the request. The Mapping Table **202** is used to translate the logical block addresses specified in the commands received from the Host **200** into addresses that point to the actual physical disk locations. The Mapping Table **202** is created based on the RAID system configuration. The plurality of Slave Disks **205** and the RAID Controller **207** are linked together via IO Bus **204**, which could include any of the existing IO interfaces available today, such as SCSI, SATA, PCIe, or an equivalent interface.

FIG. **3** illustrates a write operation implementation for a typical prior art RAID-5 system. RAID-5 is one of the most common protection techniques against failed disks. This

RAID configuration works by striping data and parity information across all the slave disks. In FIG. **3**, Host **300** issues a write command **308** to the RAID Controller **307**. The write data **309** is stored in the RAID Cache **306**. The RAID Controller after referring to its Mapping Table **302** determines that the write data in the RAID Cache **306** should be striped across the plurality of slave disks **305**. The RAID Controller issues an IO write command **310** to write data stripe **0 314** to Slave Disk **1 318**, an IO write command **311** to write data stripe **1 315** to Slave Disk **2 319** and an IO write command **312** to write data stripe **2 316** to Slave Disk **3 320**. The RAID Controller also generates the corresponding parity stripe **317** by XORing the data stripes. This parity stripe is written by the RAID Controller to Slave Disk N **321** by issuing another IO write command **313**.

FIG. **4** illustrates a read operation implementation for a typical prior art RAID-5 system. Host **400** issues a read command **408** to the RAID Controller **407**. The RAID Controller checks its Mapping Table **402** to determine from which slave disks **405** the data will come from. The RAID controller then issues an IO read command **414** to Slave Disk **1 410** to get data stripe **417**, an IO read command **415** to Slave Disk **2 411** to get data stripe **418** and an IO read command **416** to Slave Disk **3 412** to get data stripe **419**. These data stripes are stored and reconstructed in RAID Cache **406** before being sent to the Host **400** as the read data **409**. In some cases, parity checking is performed during read operation in which case the parity stripe is read from the other disk and then XORed to all the data stripes read from the rest of the slave disks.

FIG. **5** illustrates a read-modify-write operation implementation for a typical prior art RAID-5 system. Read-modify-write occurs whenever the Host requests to write only a data stripe instead of the whole data block. Host **500** sends a write command **512** to the RAID Controller **507**. The RAID Controller receives the write data **513** and stores it in the RAID Cache **506**. After referring to the Mapping Table **502**, the RAID Controller discovers that the write request involves a write of only a data stripe. The RAID Controller then issues an IO read command **514** to the Slave Disk **1 508** to read the old data stripe **515**. The old data stripe **515** is XORed with the new data stripe stored in the RAID Cache **506** using the XOR Engine **503**. The result of the XOR operation is temporarily stored in the RAID Cache **506**. The new data stripe is still kept in the RAID Cache. The RAID Controller then issues an IO read command **518** to the Slave Disk N **511** to read the old parity **519**. The old parity **519** is then XORed with the result of the previous XOR operation using the XOR Engine **503**. The result of this XOR operation, the new parity, is again stored in the RAID Cache **506**. After generating the new parity, the RAID Controller **507** issues an IO write command **516** to the Slave Disk **1 508** to write the new data stripe **517** from the RAID Cache **506**. The RAID Controller also issues an IO write command **520** to the Slave Disk N **511** to write the new parity **521** from the RAID Cache **506**. This completes the read-modify-write operation.

FIG. **6** illustrates the modified Flash Electronic Disk Architecture. In this invention, the RAID features are incorporated into the Flash Electronic Disk by adding the RAID components in the Flash Controller. The Flash Electronic Disk **608** is upgraded with the addition of the RAID Control Module **607**, which handles the RAID capabilities of the invention. The RAID Control Module contains an XOR Engine **603** that is used during parity calculations, a RAID Cache **606** that serves as the temporary data storage during parity calculations and a Mapping Table **602** for address translation of the commands received from the Host **600**.

In a computer system where RAID is needed, the Flash Electronic Disk in FIG. **6** becomes a ready RAID Controller eliminating the need for a separate hardware entity. The plurality of Flash Memory Devices **605** serves as the non-volatile cache of the RAID system. The Flash Memory Devices are used to store recently used information for the RAID system. The Flash Controller **601** partitions the Flash Memory Devices **605** into stripes and records the boundaries. The Flash Controller passes these boundaries to the RAID Control Module **607** for inter-disk striping of RAID. The use of these flash memory devices as cache significantly enhances the performance of the RAID system because they reduce frequent access to slower storage devices such as HDD.

The Flash Electronic Disk of FIG. **6** is also capable of handling master and slave roles in a RAID system. The plurality of Flash Memory Devices **605** may be used as a slave disk instead of a cache. The memory locations of the Flash Memory Devices are remapped on a new addressing scheme kept by the RAID Control Module **607** in its Mapping Table **602**. In addition, it is possible to distribute the flash memory devices to a number of RAID systems. The Flash Electronic Disk can have one flash memory device assigned to its RAID Control Module **607**, and the rest of its Flash Memory Devices **605** assigned to different RAID controllers in other RAID systems. This way, the Flash Electronic Disk **608** can participate in multiple RAID systems rather just one, and can also take dual roles depending on which RAID system it is in.

Furthermore, the plurality of Flash Memory Devices **605** can be configured as replacement disks or "hot spares". The availability of replacement disks allows the RAID Control Module **607** to perform reconstruction. Reconstruction is a background process executed in the RAID system to regenerate the data from the failed disk. This process involves reading the data from the surviving slave disks for each stripe, calculating the parity of that data and then writing this value to the replacement disk. Reconstruction works both for data and parity disks since the XOR operation is commutative. The performance of the RAID system is degraded while a failed disk is being rebuilt. However, the RAID system continues to function in such a way that all data are still accessible by the Host including that from the failed disk.

FIG. **7** shows a RAID system consisting of ordinary disks and the Flash Electronic Disk according to an embodiment of the present invention. The Flash Electronic Disk is labeled as the "Master Disk" **704** to differentiate it from the Slave Disks **710** in the RAID system **711**. The RAID Control Module **709** of the Master Disk **704** is configured to be the RAID Controller of the RAID system **711**. The Master Disk **704** comprising of a Flash Controller **703** along with the Flash Interconnect **706** and the plurality of Flash Memory Devices **707**, used as the system cache, communicates with the Slave Disks **710** through the one or more generic IO Bus **701**, such as SCSI, SATA, PCIe, or an equivalent IO Bus. The slave disks of the RAID system **711** may be any other disk, HDD or SSD, as long as it can interface with the one or more IO Bus **701**. The RAID Control Module **709** has its own XOR Engine **705** for parity calculations, a RAID Cache **708** for temporary storage of data and a Mapping Table **702** for translating the commands received for the RAID system.

FIG. **8** is the write operation implementation in a Flash Electronic Disk taking a master role in a RAID-5 system according to an embodiment of the present invention. The

Master Disk **804** receives a write command **812** from the Host **800**. The write data **813** is stored in the RAID Cache **808** of the RAID Control Module **809**. The RAID Control Module after referring to its Mapping Table **802** determines that the write data in the RAID Cache **808** should be striped across the plurality of slave disks **810**. The RAID Control Module translates the write request received from the Host **800** into multiple write accesses to the plurality of slave disks by converting the write data **813** into data stripes. The RAID Control Module also generates the corresponding parity stripe by XORing all the data stripes using its XOR Engine **805**. This parity stripe is temporarily stored in the RAID Cache **808** along with the data stripes.

However, instead of accessing the slave disks frequently, the Master Disk **804** decides to first write the data stripes to its Flash Memory Devices **807**. The Flash Memory Devices **807**, being the system cache, contains the recently used information for the RAID system **811**. The Flash Controller **803** therefore issues a flash write command **814** to write data stripe **0 818** to Flash Memory Device **1 822**, a flash write command **815** to write data stripe **1 819** to Flash Memory Device **1 823** and a flash write command **816** to write data stripe **2 820** to Flash Memory Device **1 824**. The Flash Controller also issues a flash write command **817** to write the parity stripe **821** to Flash Memory Device N **825**. The data and parity stripes stored in the plurality of Flash Memory Devices **807** are periodically flushed to the plurality of Slave Disks **810**.

FIG. **9** illustrates how the Flash Electronic Disk performs the flushing process according to an embodiment of the present invention. The plurality of the Flash Memory Devices **907** acts as the system cache of the RAID system **911**. The contents of the Flash Memory Devices are regularly transferred to the Slave Disks. Flash Memory Device **1 920** is the cache of the Slave Disk **1 932**. Flash Memory Device **2 921** is the cache of the Slave Disk **2 933**. Flash Memory Device **3 922** is the cache of the Slave Disk **3 934**. Flash Memory Device N **923** is the cache of the Slave Disk N **935**. During flushing, the Flash Controller **903** issues a flash read command **912** to Flash Memory Device **1 920** to transfer the data block **0 916** to the RAID Cache **908**. The Flash Controller then issues an IO write command **928** to Slave Disk **1 932** to transfer the same data block **0 924** from RAID Cache **908** to Slave Disk **1 932**. In the same way, the Flash Controller **903** issues a flash read command **913** to Flash Memory Device **2 921** to transfer the data block **1 917** to the RAID Cache **908**. The Flash Controller then issues an IO write command **929** to Slave Disk **2 933** to transfer the same data block **1 925** from RAID Cache **908** to Slave Disk **2 933**. For Flash Memory Device **3 922**, the Flash Controller **903** issues a flash read command **914** to Flash Memory Device **3 922** to transfer the data block **2 918** to the RAID Cache **908**. The Flash Controller then issues an IO write command **930** to Slave Disk **3 934** to transfer the same data block **2 926** from RAID Cache **908** to Slave Disk **3 934**. And lastly for Flash Memory Device N **923**, the Flash Controller **903** issues a flash read command **915** to Flash Memory Device N **923** to transfer the data block N-**1 919** to the RAID Cache **908**. The Flash Controller then issues an IO write command **931** to Slave Disk N **935** to transfer the same data block N-**1 927** from RAID Cache **908** to Slave Disk N **935**.

FIG. **10** is the read operation implementation in a Flash Electronic Disk taking a master role in a RAID-5 system according to an embodiment of the present invention. Host **1000** issues a read command **1012** to the Master Disk **1004**. The RAID Control Module **1009** determines that the requested data is striped across the plurality of slave disks **1010**. The RAID Control Module translates the read request received from the Host **1000** into multiple read accesses to the plurality of slave disks by reading the corresponding data stripes. The RAID Control Module **1009** of the Master Disk checks its Mapping Table **1002** to determine from which slave disks **1010** the data stripes will come from.

However, instead of accessing the slave disks frequently, the Master Disk **1004** in one embodiment can decide to read the data stripes from its Flash Memory Devices **1007**. The Flash Memory Devices **1007**, being the system cache, contains the recently accessed information for the RAID system **1011**. The Flash Controller **1003** therefore issues a flash read command **1014** to Flash Memory Device **1 1020** to get data stripe **1017**, a flash read command **1015** to Flash Memory Device **2 1021** to get data stripe **1018** and a flash read command **1016** to Flash Memory Device **3 1022** to get data stripe **1019**. These data stripes are stored and reconstructed in RAID Cache **1008** before being sent to the Host **1000** as the read data **1013**.

FIG. **11** is the read-modify-write operation implementation in a Flash Electronic Disk taking a master role in a RAID-5 system according to an embodiment of the present invention. Host **1100** sends a write command **1112** to the Master Disk **1104**. The RAID Control Module **1109** of the Master Disk receives the write data **1113** and stores it in the RAID Cache **1108**. After referring to the Mapping Table **1102**, the RAID Control Module discovers that the write request involves a write of only a data stripe. A write of only a data stripe involves a read-modify-write operation. The RAID Control Module first checks from which slave disks will the old data stripe and old parity stripe come from. The RAID Control Module determines that the old data stripe should come from Slave Disk **1** and the old parity stripe should come from Slave Disk N.

However, instead of accessing the slave disks frequently, the Master Disk **1104** decides to read these stripes from its Flash Memory Devices **1107**. The Flash Memory Devices **1107**, being the system cache, contains the recently accessed information for the RAID system **1111**. The Flash Controller **1103** therefore issues a flash read command **1114** to the Flash Memory Device **1 1122** to read the old data stripe **1118**. The old data stripe **1118** is XORed with the new data stripe **1113** stored in the RAID Cache **1108** using the XOR Engine **1105**. The result of the XOR operation is temporarily stored in the RAID Cache **1108**. The new data stripe is still kept in the RAID Cache. The Flash Controller then issues a flash read command **1116** to the Flash Memory Device N **1125** to read the old parity **1120**. The old parity **1120** is then XORed with the result of the previous XOR operation using the XOR Engine **1105**. The result of this XOR operation, the new parity, is again stored in the RAID Cache **1108**. After generating the new parity, the Flash Controller **1103** issues a flash write command **1115** to the Flash Memory Device **1 1122** to write the new data stripe **1119** from the RAID Cache **1108**. The Flash Controller also issues a flash write command **1117** to the Flash Memory Device N **1125** to write the new parity **1121**.

FIG. **12** is the write operation implementation in a Flash Electronic Disk taking dual roles in a RAID-5 system according to an embodiment of the present invention. In this implementation, the RAID Control Module **1209** of the Master Disk **1204** is configured as the RAID Controller of the RAID system **1211**. The Flash Memory Device **1 1212** of the Master Disk, along with the Slave Disks **1220**, **1221**, **1222** act as the RAID Slave Disks with the data striped across all the slave disks.

The Flash Controller **1203** of the Master Disk **1204** receives a write command **1218** along with the write data **1219** from the Host **1200**. The Flash Controller stores the write data **1219** it received from the Host **1200** in the RAID Cache **1208**. Based from the Mapping Table **1202** of the RAID Control Module **1209**, the data sent by the Host **1200** should be striped across all the RAID Slave Disks. The RAID Control Module translates the write request received from the Host **1200** into multiple write accesses by converting the write data **1219** into data stripes. The RAID Control Module also generates the corresponding parity stripe by XORing all the data stripes using its XOR Engine **1205**. This parity stripe is temporarily stored in the RAID Cache **1208** along with the data stripes. The Flash Controller **1203** then issues a flash write command **1216** to write data stripe **0** **1217** to Flash Memory Device **1** **1212**, an IO write command **1224** to write data stripe **1** **1223** to Slave Disk **2** **1220** and an IO write command **1226** to write data stripe **2** **1225** to Slave Disk **3** **1221**. The Flash Controller also issues an IO write command **1228** to write the parity stripe **1227** to Slave Disk N **1222**.

FIG. **13** is the read operation implementation in a Flash Electronic Disk taking dual roles in a RAID-5 system according to an embodiment of the present invention. In this implementation, the RAID Control Module **1309** of the Master Disk **1304** is configured as the RAID Controller of the RAID system **1311**. The Flash Memory Device **1** **1312** of the Master Disk, along with the Slave Disks **1324**, **1325**, **1326** act as the RAID Slave Disks with the data striped across all the slave disks.

The Flash Controller **1303** of the Master Disk **1304** receives a read command **1318** from the Host **1300**. The RAID Control Module **1309** being the RAID Controller of the RAID system **1311** interprets the command by referring to its Mapping Table **1302**. Based from the Mapping Table, the data being requested by the Host **1300** is found to be striped across all the RAID Slave Disks. The Flash Controller then creates the corresponding Flash Read command for the Flash Memory Device and IO Read commands for the other Slave Disks. A Flash Read command **1316** is sent to Flash Memory Device **1** **1312** to get the data stripe **0** **1317**. An IO Read command **1321** is sent to Slave Disk **2** **1324** to get the data stripe **1** **1320**. An IO Read command **1323** is sent to Slave Disk **3** **1325** to get the data stripe **2** **1322**. The data stripes received from the Flash Memory Device and the Slave Disks are reconstructed in the RAID Cache **1308** and then sent to the requesting Host **1300** as the read data **1319**.

FIG. **14** is the read-modify-write operation implementation in a Flash Electronic Disk taking dual roles in a RAID-5 system according to an embodiment of the present invention. In this implementation, the RAID Control Module **1409** of the Master Disk **1404** is configured as the RAID Controller of the RAID system **1411**. The Flash Memory Device **1** **1418** of the Master Disk, along with the Slave Disks **1422**, **1423**, **1424** act as the RAID Slave Disks with the data striped across all the slave disks.

Host **1400** sends a write command **1412** to the Master Disk **1404**. The RAID Control Module **1409** of the Master Disk receives the write data **1413** and stores it in the RAID Cache **1408**. After referring to the Mapping Table **1402**, the RAID Control Module discovers that the write request involves a write of only a data stripe. A write of only a data stripe involves a read-modify-write operation. The RAID Control Module first checks from which slave disks will the old data stripe and old parity stripe come from. The RAID Control Module determines that the old data stripe should come from Flash Memory Device **1** and the old parity stripe should come from Slave Disk N.

The Flash Controller **1403** issues a flash read command **1417** to the Flash Memory Device **1** **1418** to read the old data stripe **1416**. The old data stripe **1416** is XORed with the new data stripe **1413** stored in the RAID Cache **1408** using the XOR Engine **1405**. The result of the XOR operation is temporarily stored in the RAID Cache **1408**. The new data stripe is still kept in the RAID Cache. The Flash Controller then issues an IO read command **1425** to the Slave Disk N **1424** to read the old parity **1426**. The old parity **1426** is then XORed with the result of the previous XOR operation using the XOR Engine **1405**. The result of this XOR operation, the new parity, is again stored in the RAID Cache **1408**. After generating the new parity, the Flash Controller **1403** issues a flash write command **1414** to the Flash Memory Device **1** **1418** to write the new data stripe **1415** from the RAID Cache **1408**. The Flash Controller also issues an IO write command **1428** to the Slave Disk N **1424** to write the new parity **1427**.

FIG. **15** is a configuration of four Flash Electronic Disks in a RAID System according to an embodiment of the present invention. Each of the four Flash Electronic Disks **1500**, **1501**, **1502** and **1503** has a RAID Control Module **1504**, **1505**, **1506** and **1507**. All other disk modules are hidden, as the focus is on the role of the RAID Control Modules. The Flash Electronic Disks are interconnected via the one or more generic IO Interface. If the Flash Memory Devices in each Flash Electronic Disk are partitioned in such a way that it allows multiple RAID systems to access it, each Flash Electronic Disk can participate in multiple RAID systems and take on dual roles—RAID Master or Slave Disk. For example, Host **0** **1508** configures Flash Electronic Disk **0** **1500** to become a RAID Controller with Flash Electronic Disk **1** **1501**, Flash Electronic Disk **2** **1502** and Flash Electronic Disk **3** **1503** as its slave disks. For clarity, the RAID system defined by Host **0** **1508** is labeled as RAID System **0**. Under RAID System **0**, the RAID Control Modules **1505**, **1506**, and **1507** take on the Slave mode. In RAID System **1**, Host **1509** configures the RAID Control Module **1505** to take the Master role while RAID Control Modules **1504**, **1506** and **1507** take slave roles. The same goes for RAID System **2** which has **1510** as the Host and RAID Control Module **1506** as its Master, and RAID System **3** which has **1511** as the Host and **1507** as the RAID Control Module. FIG. **15** shows a possible configuration of Flash Electronic Disks in one embodiment employing the invention used to its full potential in RAID systems. It shows 4 computer systems using four Flash Electronic Disks in four distinct RAID Systems **0**, **1**, **2** and **3**.

FIG. **16**. summarizes the multi-RAID configuration of multiple Flash Electronic Disks according to an embodiment of the present invention. Column **1602** lists the Flash Electronic Disks **0**, **1**, **2**, **3**, and N respectively in rows **1620**, **1622**, **1624**, **1626**, and **1628**. Columns **1604**, **1606**, **1608**, **1610**, and **1612** list the Raid System **0**, **1**, **2**, **3**, and N, respectively. More Flash Electronic Disks can be added to the configuration of FIG. **15** to produce multiple RAID systems on a plurality of disks. The RAID system becomes more stable and data integrity is high. The configuration also allows non flash electronic disks to be inserted into the RAID system, as long as it conforms to the IO Interface, but its role will be limited only to being a slave, and its address map is limited only to the RAID system where its RAID Controller is attached to.

FIG. **17** illustrates a method to operationally integrate one or more RAID control mechanisms into a flash electronic disk controller, in accordance with one embodiment of the invention. The method starts in operation **1702**. Operation **1704** is next and includes incorporating one or more RAID features into a flash electronic disk by adding one or more RAID components in a flash controller, wherein the flash electronic disk is upgraded with the addition of a RAID control module to control the one or more RAID components. Operation **1706** is next and includes receiving a read or write operation command at the flash electronic disk controller from a host. Operation **1708** is next and includes translating the read or write operation command into a command format understood by one or more flash controllers. Operation **1710** is next and includes translating the command format into an instruction format understood by one or more flash memory devices. Operation **1712** is next and includes accessing one or more memory locations in the one or more flash memory devices according to the instruction format to perform a read or write operation for the host. The method ends in operation **1714**.

Foregoing described embodiments of the invention are provided as illustrations and descriptions. They are not intended to limit the invention to precise form described. In particular, it is contemplated that functional implementation of invention described herein may be implemented equivalently in hardware, software, firmware, and/or other available functional components or building blocks, and that networks may be wired, wireless, or a combination of wired and wireless.

It is also within the scope of the present invention to implement a program or code that can be stored in a machine-readable or computer-readable medium to permit a computer to perform any of the inventive techniques described above, or a program or code that can be stored in an article of manufacture that includes a computer readable medium on which computer-readable instructions for carrying out embodiments of the inventive techniques are stored. Other variations and modifications of the above-described embodiments and methods are possible in light of the teaching discussed herein.

The above description of illustrated embodiments of the invention, including what is described in the Abstract, is not intended to be exhaustive or to limit the invention to the precise forms disclosed. While specific embodiments of, and examples for, the invention are described herein for illustrative purposes, various equivalent modifications are possible within the scope of the invention, as those skilled in the relevant art will recognize.

These modifications can be made to the invention in light of the above detailed description. The terms used in the following claims should not be construed to limit the invention to the specific embodiments disclosed in the specification and the claims. Rather, the scope of the invention is to be determined entirely by the following claims, which are to be construed in accordance with established doctrines of claim interpretation.

What is claimed is:

1. An apparatus, comprising:

an IO (Input/Output) bus;

a host coupled to the IO bus;

a flash electronic disk coupled via the IO bus to the host, wherein the flash electronic disk incorporates one or more RAID features, said flash electronic disk comprising a flash controller having one or more RAID components, wherein the flash electronic disk includes a RAID control module to control the one or more RAID components, wherein the flash controller receives a read operation command or write operation command from the host and translates the read operation command or write operation command into a command format that can be understood by one or more flash memory devices;

wherein the flash electronic disk further comprises one or more flash memory devices and a flash interconnect coupled to the flash controller and to the one or more flash memory devices;

wherein the flash controller is configured to translate the command format into an instruction format that can be understood by the one or more flash memory devices;

wherein the one or more flash memory devices include one or more memory locations that can be accessed according to the instruction format to perform a read operation or write operation for the host;

wherein the flash interconnect is configured to handle data transmission between the host and the one or more flash memory devices;

wherein the flash memory devices comprise at least a first flash memory device, a second flash memory device, and a third flash memory device;

wherein the RAID control module in the flash controller is configured to distribute data from the host across the flash memory devices by data striping;

wherein the RAID control module distributes a first data stripe of the data into the first flash memory device, distributes a second data stripe of the data into the second flash memory device, and distributes a parity of the data into the third flash memory device;

wherein the flash controller is coupled to the IC bus;

a plurality of disks coupled to the IC bus, wherein the plurality of disks comprises a first disk, a second disk, and a third disk;

wherein the flash controller transfers the first data stripe in the first flash memory device to the first disk;

wherein the flash controller transfers the second data stripe in the second flash memory device to the second disk; and

wherein the flash controller transfers the parity of the data in the third flash memory device to the third disk.

2. The apparatus of claim **1**, wherein:

the RAID control module comprises a RAID cache that serves as a temporary data storage during one or more parity calculations.

3. The apparatus of claim **1**, wherein:

the RAID control module comprises a mapping table for address translation of the read operation and write operation commands received from the host.

4. The apparatus of claim **1**, wherein:

the RAID control module comprises an XOR engine that is used during one or more parity calculations.

5. The apparatus of claim **1**, wherein:

the RAID control module comprises an XOR engine that is used during one or more parity calculations, a RAID cache that serves as a temporary data storage during one or more parity calculations and a mapping table for address translation of the read operation and write operation commands received from the host.

6. The apparatus of claim **1**, wherein the one or more flash memory devices are used as a slave disk instead of a cache memory.

7. The apparatus of claim **1**, wherein the one or more flash memory devices are used as a slave disk instead of a cache memory by remapping a plurality of memory locations of the one or more flash memory devices on a new addressing scheme kept by the RAID control module in a mapping table.

8. The apparatus of claim **1**, wherein the one or more flash memory devices are distributed to a number of RAID systems, wherein the flash electronic disk has one or more flash memory devices assigned to the RAID control module, and a remainder of the flash memory devices are assigned to another RAID control module in another RAID system.

9. The apparatus of claim **1**, wherein the one or more flash memory devices are used as hot spare replacement disks.

10. The apparatus of claim **1**, wherein the one or more flash memory devices are used as hot spare replacement disks, wherein one or more replacement disks allow the RAID control module to perform reconstruction to regenerate data from a failed disk by reading the data from one or more surviving slave disks.

11. A method comprising:

incorporating one or more RAID features into a flash electronic disk by adding one or more RAID components in a flash controller, wherein the flash electronic disk includes a RAID control module to control the one or more RAID components;

receiving a read operation command or write operation command at the flash electronic disk from a host;

translating the read operation command or write operation command into a command format understood by one or more flash memory devices;

translating the command format into an instruction format understood by one or more flash memory devices;

handling, by a flash interconnect coupled to the flash controller and to the one or more flash memory devices, data transmission between the host and the one or more flash memory devices;

accessing one or more memory locations in the one or more flash memory devices according to the instruction format to perform a read operation or write operation for the host;

distributing, by the RAID control module in the flash controller, data from the host across the one or more flash memory devices by data striping;

wherein the one or more flash memory devices comprise at least a first flash memory device, a second flash memory device, and a third flash memory device;

wherein the RAID control module distributes a first data stripe of the data into the first flash memory device, distributes a second data stripe of the data into the second flash memory device, and distributes a parity of the data into the third flash memory device;

wherein the host and the flash controller are both coupled to an IC (input/output) bus;

wherein a plurality of disks is coupled to the IC bus, wherein the plurality of disks comprises a first disk, a second disk, and a third disk;

transferring, by the flash controller, the first data stripe in the first flash memory device to the first disk;

transferring, by the flash controller, the second data stripe in the second flash memory device to the second disk; and

transferring, by the flash controller, the parity of the data in the third flash memory device to the third disk.

12. The method of claim **11**, wherein incorporating the one or more RAID features into the flash electronic disk includes adding the RAID control module having a RAID cache that serves as a temporary data storage during one or more parity calculations.

13. The method of claim **11**, wherein incorporating the one or more RAID features into the flash electronic disk includes adding a mapping table for address translation of one or more read operation commands or write operation commands received from the host.

14. The method of claim **11**, wherein incorporating the one or more RAID features into the flash electronic disk includes adding the RAID control module having an XOR engine that is used during one or more parity calculations.

15. The method of claim **11**, wherein incorporating the one or more RAID features into the flash electronic disk includes adding the RAID control module having an XOR engine that is used during one or more parity calculations, adding a RAID cache that serves as a temporary data storage during the one or more parity calculations and adding a mapping table for address translation of the read operation or write operation commands received from the host.

16. The method of claim **11**, wherein the one or more flash memory devices are used as a slave disk instead of a cache memory.

17. The method of claim **11**, wherein the one or more flash memory devices are used as a slave disk instead of a cache memory and a plurality of memory locations of the flash memory devices are remapped on a new addressing scheme kept by the RAID control module in a mapping table.

18. The method of claim **11**, wherein the one or more flash memory devices are used as a slave disk instead of a cache memory and a plurality of memory locations of the flash memory devices are remapped on a new addressing scheme kept by the RAID control module in a mapping table, and the one or more flash memory devices are distributed among one or more other RAID systems by assignment to one or more RAID controllers for the one or more other RAID systems.

19. The method of claim **11**, wherein the one or more flash memory devices are used as hot spare replacement disks, wherein one or more replacement disks allow the RAID control module to perform reconstruction to regenerate data from a failed disk by reading the data from one or more surviving slave disks.

20. A method comprising:

incorporating one or more RAID features into a flash electronic disk by adding one or more RAID components in a flash controller, wherein the flash electronic disk includes a RAID control module to control the one or more RAID components, including adding the RAID control module having an XOR engine that is used during one or more parity calculations, adding a RAID cache that serves as a temporary data storage during the one or more parity calculations and adding a mapping table for address translation of one or more commands received from a host;

receiving a read operation command or write operation command at the flash electronic disk from the host;

translating the read operation command or write operation command into a command format understood by one or more flash memory devices;

translating the command format into an instruction format understood by one or more flash memory devices;

handling, by a flash interconnect coupled to the flash controller and to the one or more flash memory devices, data transmission between the host and the one or more flash memory devices;

accessing one or more memory locations in the one or more flash memory devices according to the instruction format to perform a read operation or write operation for the host;

distributing, by the RAID control module in the flash controller, data from the host across the one or more flash memory devices by data striping;

wherein the one or more flash memory devices comprise at least a first flash memory device, a second flash memory device, and a third flash memory device;

wherein the RAID control module distributes a first data stripe of the data into the first flash memory device, distributes a second data stripe of the data into the second flash memory device, and distributes a parity of the data into the third flash memory device;

wherein the host and the flash controller are both coupled to an IC (input/output) bus;

wherein a plurality of disks is coupled to the IC bus, wherein the plurality of disks comprises a first disk, a second disk, and a third disk;

transferring, by the flash controller, the first data stripe in the first flash memory device to the first disk;

transferring, by the flash controller, the second data stripe in the second flash memory device to the second disk; and

transferring, by the flash controller, the parity of the data in the third flash memory device to the third disk.

21. An apparatus comprising:

a flash electronic disk comprising:

a flash controller, wherein the flash controller includes a RAID controller;

a plurality of flash memory devices; and

a flash interconnect coupled to the flash controller and to the plurality of flash memory devices;

wherein the flash electronic disk receives write and read commands from a host;

wherein the flash controller is configured to translate the write and read commands into flash native commands which are understood by the plurality of flash memory devices;

wherein the flash interconnect is configured to handle data transmission between the host and the plurality of flash memory devices;

wherein the plurality of flash memory devices comprises at least a first flash memory device, a second flash memory device, and a third flash memory device;

wherein the RAID controller in the flash controller is configured to distribute data from the host across the plurality of flash memory devices by data striping;

wherein the RAID controller distributes a first data stripe of the data into the first flash memory device, distributes a second data stripe of the data into the second flash memory device, and distributes a parity of the data into the third flash memory device;

wherein the flash controller and the host are both coupled to an IC (input/output) bus;

wherein a plurality of disks is coupled to the IO bus, wherein the plurality of disks comprises a first disk, a second disk, and a third disk;

wherein the flash controller transfers the first data stripe in the first flash memory device to the first disk;

wherein the flash controller transfers the second data stripe in the second flash memory device to the second disk; and

wherein the flash controller transfers the parity of the data in the third flash memory device to the third disk.

22. The apparatus of claim **21**, wherein the RAID controller comprises an XOR engine that is used during one or more parity calculations, a RAID cache that serves as a temporary data storage during one or more parity calculations, and a mapping table for address translation of the write and read commands received from the host.

23. A method comprising:

receiving, by a flash electronic disk, write and read commands from a host;

translating, by a flash controller in the flash electronic disk, the write and read commands into flash native commands which are understood by a plurality of flash memory devices in the flash electronic disk;

handling, by a flash interconnect coupled to the flash controller and to the plurality of flash memory devices, data transmission between the host and the plurality of flash memory devices;

distributing, by a RAID controller in the flash controller, data from the host across the plurality of flash memory devices by data striping;

wherein the plurality of flash memory devices comprises at least a first flash memory device, a second flash memory device, and a third flash memory device;

wherein the RAID controller distributes a first data stripe of the data into the first flash memory device, distributes a second data stripe of the data into the second flash memory device, and distributes a parity of the data into the third flash memory device;

wherein the host and the flash controller are both coupled to an IO (input/output) bus;

wherein a plurality of disks is coupled to the IO bus, wherein the plurality of disks comprises a first disk, a second disk, and a third disk;

transferring, by the flash controller, the first data stripe in the first flash memory device to the first disk;

transferring, by the flash controller, the second data stripe in the second flash memory device to the second disk; and

transferring, by the flash controller, the parity of the data in the third flash memory device to the third disk.

24. The method of claim **23**, wherein the RAID controller comprises an XOR engine that is used during one or more parity calculations, a RAID cache that serves as a temporary data storage during one or more parity calculations, and a mapping table for address translation of the write and read commands received from the host.

25. An article of manufacture, comprising:

a non-transitory computer-readable medium having stored thereon instructions operable to permit an apparatus to:

receive, by a flash electronic disk, write and read commands from a host;

translate, by a flash controller in the flash electronic disk, the write and read commands into flash native commands which are understood by a plurality of flash memory devices in the flash electronic disk;

handle, by a flash interconnect coupled to the flash controller and to the plurality of flash memory devices, data transmission between the host and the plurality of flash memory devices;

distribute, by a RAID controller in the flash controller, data from the host across the plurality of flash memory devices by data striping;

wherein the plurality of flash memory devices comprises at least a first flash memory device, a second flash memory device, and a third flash memory device;

wherein the RAID controller distributes a first data stripe of the data into the first flash memory device, distributes a second data stripe of the data into the second flash memory device, and distributes a parity of the data into the third flash memory device;

wherein the host and the flash controller are both coupled to an IO (input/output) bus;

wherein a plurality of disks is coupled to the IO bus, wherein the plurality of disks comprises a first disk, a second disk, and a third disk;

transfer, by the flash controller, the first data stripe in the first flash memory device to the first disk;

transfer, by the flash controller, the second data stripe in the second flash memory device to the second disk; and

transfer, by the flash controller, the parity of the data in the third flash memory device to the third disk.

26. The article of manufacture of claim **25**, wherein the RAID controller comprises an XOR engine that is used during one or more parity calculations, a RAID cache that serves as a temporary data storage during one or more parity calculations, and a mapping table for address translation of the write and read commands received from the host.

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